CHAPTER 2.

NAVAL RADAR EQUIPMENT.

GET TO GRIPS WITH YOUR RADAR.

RADAR is one of the most revolutionary assets which has come to the Navy since King Alfred made his culinary error. It is comparable with the change from sail to steam. Its full and efficient deployment, however, depends upon the officers who command its use. It is unfortunately true that, in a very large number of cases, its employment is based on ignorance, and even suspicion. There is still a tendency to imagine that RADAR is based on principles which the average mortal cannot understand, and that its problems will be settled by the RADAR branch.

In actual fact, there is no RADAR branch as such. The position of RADAR in the Navy is analogous to seamanship. It is the responsibility of all. Any officer is liable to be detailed to take over RADAR responsibilities, whether specialist or no.

It is hoped that Chapter I has gone some way towards dispelling the prevalent idea that RADAR is Black Magic. It is desired in this chapter to make it perfectly plain that, whereas in pure wireless it does not matter to the officer whether his signal is made on type 48, 49 or 65, in RADAR the type number matters very considerably. Confusing though the numbers may be at first, type 284 must mean something to the officer in terms of fighting efficiency and hitting power. There can be no shirking this.

An Officer of the Watch would not think of arriving on the bridge without being equipped with binoculars. Furthermore, he learns how to use them, in order to increase the distance at which he can sight suspicious objects, and improve his general alertness; but for some unknown reason, he will not give a thought to an instrument which gives him vision up to 20 miles against surface objects, and 100 miles against aircraft, when he cannot see his hand in front of his face with the human eye.

Similarly, an officer takes it as his duty to study the guns with which his ship is fitted, and appreciate their fire-power, range and accuracy. He even takes pride in, and boasts of the gun-power of his ship. RADAR will not find its rightful place in the Navy until it is put on the same level. Officers have got to take it as their duty to know what the RADAR equipment in their ship is doing for them, and how to use it; and when boasting that their ship is fitted with this or that number of guns - add: "and RADAR types 277, 274 and 275". There can be no real admiration for the ship today without that last appreciation.

Apart from this, officers should also be able to look at a ship and take in at a glance the RADAR equipment which is fitted. To do this it is not necessary to take the sea-boat over and look in the RADAR office, for every RADAR set has its own peculiar aerial system, and can easily be recognised. Officers must be able to look at a ship and advise their Admiral or Captain on the rightful place for that ship to occupy in the disposition of the Fleet; for it will, or should, be profoundly affected by the RADAR equipment of which she boasts. For this reason, diagrams have been prepared tabulating the Warning and Gunnery equipment, the last column of which shows the associated aerial system.

A RADAR frequency spectrum has also been prepared which shows where the various types of equipment lie in frequency with reference to each other. Sets are designed to fulfil certain requirements, and are classified under several general headings. Different frequencies fulfil different requirements.

THE PROCESS OF PRODUCTION.

The process is very often a slow one, judged by wartime standards, but it usually has the virtue of being sure. Scientists design a set to certain staff requirements, and perhaps one or two models are produced. These are sent to sea, where they do extensive trials in all sorts of conditions. They return to the designer to the accompaniment, usually, of a host of complaints. A number of modifications are introduced, and the set goes to sea again.

This process may be repeated again perhaps twice before the final design is decided upon. It may take between 2½ to 3 years before the set reaches its final form, and long though this period is, the equipment at the end of it usually gives continuous good service both from the operational and maintenance point of view. Type 79 is a typical example of this procedure. It was produced sometime before the war, and is still going strong and has given less trouble than any other set designed since. The necessities of wartime demand that this somewhat leisurely procedure be cut down to a minimum, and many of the troubles with which we have had to contend today in RADAR equipment produced since this war started, have been due to this.

THE BIRTH OF RADAR.

It is interesting to trace a short history of the start of RADAR and its development up to the present-day standard.

It was as early as 1935 that H.M.Government began to consider the question of warning against air attack from the Continent of Europe. The whole organisation of the Fighter Defence of Great Britain depended on sufficient warning of the approach of enemy aircraft being available. It was essential that Fighters should be kept on the ground waiting to meet the assault when it came. To maintain fighter patrols in the air, in strength, is probably not possible even today, when our air power is at its height.

This vital problem was handed over to our leading scientists of the day to investigate, as to whether there was any means known to science which would give us this time interval; which was, in fact, as it turned out in the Battle of Britain, a life and death need.

Mr. Watson Watt, now Sir Robert Watson Watt, stated that he had been engaged in employing the reflecting properties of electro-magnetic waves to determine the height of the ionosphere - and it would appear at first sight that this could be applied to aircraft. It had also been observed that when aircraft were flying in the vicinity of Television Stations and Receivers, a double picture sometimes appeared. This strengthened the belief that reflections could, in fact, be obtained from aircraft, which was the only way these double images could be accounted for.

As is now well-known, development and production then went ahead to produce a coastal chain of Warning Stations round our coasts, which were to play so vital a part in saving Britain from defeat in the anxious days of 1940.

The potentialities of such valuable equipment were immediately apparent to the Navy, for whom warning of air attack was equally a vital need; but as in all material fitted in ships, and particularly warships, great practical difficulties have to be overcome. Indeed, usually severe limitations are suffered when compared to the same equipment set up ashore - and RADAR equipment is no exception to this. The siting of the aerial system, for instance, has to be a compromise between considerations of topweight, field of view, and the design of the reflecting system.

H.M.Signal School, however, set to work to design equipment which could be fitted in ships. At first, it was largely a matter of designing valves which would produce a wavelength short enough to enable the aerial system to be sited high up in the ship, without having to make prohibitive sacrifices for this additional topweight.

PROGRESS OF DEVELOPMENT.

WA sets.

Type 79: The first set to be produced was actually type 79, a WA set, which worked on a wavelength of about 7 metres. At the start of the war, two of these sets were at sea, one in the RODNEY and one in the SHEFFIELD, and 38 more were on order. It gave a horizontal lobe of 70° and a detection range of 95 miles on an aircraft at 20,000 feet. This set, as before stated, has performed with great success. Experience quickly indicated that echoes could also be obtained from surface craft, and the potentialities of this were immediately recognised as applied to Gunnery rangetaking.

Type 279: A ranging panel was designed and fitted to the 79 and it was called in this event a 279. The unsoundness of the policy of using the same set to give air warning as was to be used on a tactical basis to give Gunnery ranges was very soon realised, and there was a call for separate Gunnery sets. This is now done and 279 is obsolete, the ranging panel having been dropped.

Type 281: A new Warning set was soon brought out called 281. The reason for this was to give better cover against low fliers and it operated on about half the wavelength with a 48^{0} beam. It was more powerful than the 79, and was fitted with Beam Switching, and had an increased detection range over type 79 of about 25 miles. The better protection against low flying aircraft provided by an increased frequency is discussed in the chapter on height finding.

When a type number is succeeded by the suffix letter (B) this means that the set operates for transmitting and receiving on the same set of aerials, e.g. type 79 B, 281 B. This modification has been necessary due to the competition for sites with a clear field of view, and is particularly applicable on aircraft carriers, where two Warning sets are now fitted, and where masts are not in abundance at the best of times. Types 79, 279, 281, were all under the general classification of Air Warning sets, or WA sets. All cruisers and above have WA sets to the proportion of 75% 281, and 25% 79.

WC sets.

There was soon a call for some form of RADAR set for destroyers and small craft. No set which worked on a short enough wavelength for a destroyer to carry its aerial system was yet designed, much less in production; or at any rate, in sufficient numbers.

A Fleet Air Arm Walrus aircraft fitted with an R.A.F. Air Surface Vessel set (A.S.V.) was at this time on the slipway at Lee-on-Solent. It was observed that when the A.S.V. set was switched on the movement of shipping in the Solent could be observed.

The Navy, therefore, applied to the R.A.F., who had a very large number of these A.S.V. sets, fitted in aircraft, which worked on a wavelength of about 1.4 metres. It was considered that these could be fitted as an interim measure and would give fairly reasonable protection or warning against surface craft and aircraft. The R.A.F. were willing to release a sufficient number for our use, and these A.S.V. sets, which were classified as WC (or Warning Combined) sets, filled an important gap.

In the Navy it was called type 286 M, and the first one had a fixed aerial system, which resembled, in some respects, a bedstead, and was fitted to the foremast facing forward.

It was not a popular set, particularly because Commanding Officers had to swing their ships to obtain bearings, which were never very accurate; it had quite a large back echo up to 5,000 yards, and only gave cover between sixty degrees on either bow.

286 M quickly gave place to 286 P, which was the same set provided with a rotateable aerial, and was a considerable improvement, not only from the latter point of view, but also that this beam width was narrowed to 30^{0}. An effort was then made to increase the power, and therefore the detection range, of this set, which suffered from lack of height when used in small ships. A more powerful transmitter was, therefore, added by Admiralty Signal Establishment, and the modified set was called 286 PQ; but like all equipment of this type, it is never very satisfactory adding bits for which it was not designed, and in fact, it never seemed to develop the theoretical additional range.

Furthermore, 286 being an aircraft set, was not designed on the lines which Naval sets are. The R.A.F. do not bargain for maintenance in the air. Their maintenance is done on the ground by expert staffs, whereas in the Navy the equipment has to be maintained whilst at sea for periods up to three weeks. Lack of wavemeter and calibrator was, therefore, a further embarrassment.

Admiralty Signal Establishment had, in the meantime, been pressing on with the design of a WC set specially for light craft, and type 290 was the first product. This was not satisfactory from many points of view, both in design and performance, and after it was born the present modern WC set, type 291.

Type 291 is an extremely neat compact little set which is giving excellent results in destroyers (291), submarines (291 W), and Coastal Forces (291 U). It has proved most popular from every point of view. It has a 38° lobe, and has given reliable surface detections with good ranging accuracy up to 10 miles, and aircraft detections up to 50 miles at a reasonable height.

WS sets.

When the Wolf Pack tactics of the U-boats became established, there was an immediate outcry for greatly improved Surface Warning, or WS equipment, to be complementary to the ASDIC equipment. Concurrently, Admiralty Signal Establishment had been experimenting with wavelengths of the order of 10 cms, and the production of pencil or searchlight beams.

The development of 1,000 kilowatts in a pulse of a few millionths of a second in length, at a frequency of 3,000 mc/s, was an achievement by our scientists of the first magnitude. Indeed, the production of the 10 cm. equipment has made a major contribution towards winning the war. It appears to be far in advance of anything which our enemies have produced, and we have handed this technique over to the Americans, who also adopted it immediately.

The first set to be produced, the type 271, gave splendid results, even from corvettes, and mass production of pre-fabricated models was embarked on at first priority; and in a remarkably short space of time our escort vessels, and afterwards Fleet Units, began to be fitted.

By virtue of its short wavelength, it was possible to design paraboloid reflectors which achieved sufficient control over the beam to produce a width of only 5 or 6 degrees, and the power developed forced it forward to give a range approximating to the optical.

A corvette was able to be certain of detecting a U-boat at 7,000 yards, and a battleship at 24,000 yards. The number of submarine kills which have been directly attributable to the 271 are too numerous to catalogue.

Reference has been made to the optical range of this set. Since the frequency is beginning to approach that of light, so the range begins to approximate to this, and therefore depends on the height of eye, or height of aerial. To improve the range it is necessary to site the 271 lantern, which contains the aerial system, as high as possible.

Difficulties arise again, of course, on account of topweight, particularly because, in the pre-fabricated set the office and lantern are all cast together and are inseparable. Nor is it desirable technically to separate them more than possible, due to the very serious loss in power which occurs in the feeder lines, the matching of which will not help in frequencies of this order.

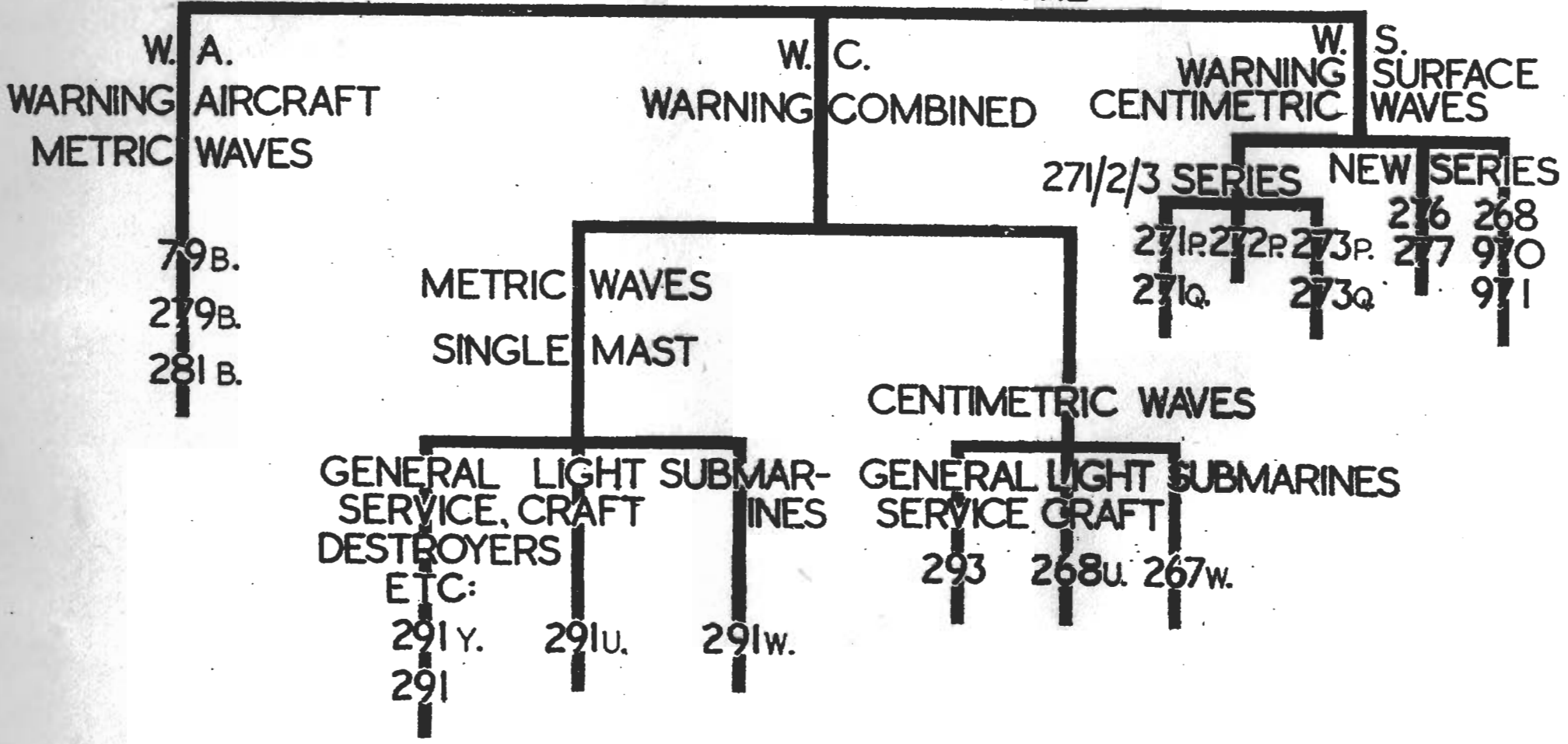
However, arrangements were made to separate office and aerial by a distance of 40 feet in order to achieve greater height of RADAR eye; and when this was done, the set was called 272.

A more powerful edition of this set was produced for capital ships and large cruisers, which had two large paraboloid reflectors, one for transmitting and one for receiving, instead of the cut-off cheeses as in the 271 - and this was called 273.

A battleship was able to be certain of some 15,000 yards detection on a U-boat, and 41,000 yards on a battleship. The lobe width was about 10°.

BRITISH SHIPBORNE WARNING RADAR

THE GENERAL PICTURE



Gunnery sets, GA, GB, GC, GS.

As previously observed, the need for separate Gunnery RADAR sets devoted to Gunnery interests only, was quickly appreciated, and at the time Admiralty Signal Establishment were experimenting on what was then a very short wavelength, 50 cms. This was judged to be a reasonable wavelength on which to design the Gunnery sets, and design and production went ahead. The results obtained justified expectations. Sets were designed to fulfil the following requirements:-

a) A ranging set to be associated with the main armament of large cruisers and above (GS type 284)

b) A ranging set to be associated with the high-angle armament of big ships and both high angle and low angle of small ships (GA,285)

c) A ranging set to be associated with barrage firing director (GB,285)

d) A ranging set to be associated with close range weapons (GC,282).

All these sets were designed on 50 cms, and were produced on much the same lines.

Type 284 and 285 were identical except for their aerial systems. The pig-trough aerial fitted on the main armament director with a 284, was obviously unsuitable for fitting to the small directors used in the H.A. control system. The YAGI, or fishbone type of aerial was, therefore, developed for the latter. The latter aerial trained and elevated with the director sight, and though a reasonable bearing accuracy could be obtained, due to the control of the beam in the horizontal plane, this was not the case in the vertical plane, and no measurement of angle of sight is possible with it.

The lobe of the 284 is 5° in width, whereas in the 285, 14° is the best that can be achieved. In 282 and 283, where there are only two Yagi aerials, the beam is of the order of 3°. The development and use of beam switching in these sets is discussed in the chapter on Gunnery.

All these sets have given thoroughly sound results and have revolutionised the accuracy of control in Naval Gunnery.

FUTURE DEVELOPMENTS.

So much for the sets which are actually at sea and serving the Fleet; a brief look into the future to enable officers to see what is coming, is desirable. Even though some of the following sets are already in the process of being fitted to sea-going ships, in limited numbers, they are still experimental.

Such has been the success of the 10 cm. technique that, with the exception of future Air Warning sets, which clearly demand long range results not achieved by a pencil beam of this nature, all our future developments have been on these lines, using a 10 cm. wavelength or even shorter.

WA sets.

The production of new Long Range Warning equipment is still some way off, but plans are in hand for the development of a set to give detection at 200 miles using a wave of 1½ to 2 metres. This is to be called type 960.

The policy at present is to design a Surface Warning set (on 10 cms) to fill in the gap underneath the 960 and thus be complementary to it. The two will be geared and rotated together and the result thrown on a combined P.P.I., or Universal Display Unit, as it will be called. This presupposes that the pulse repetition rates are the same and the pulses synchronised. In this way, it is hoped that complete cover, with no gaps, may be achieved.

WC sets.

Type 293, employing 10 cms. was originally designed to replace type 291 as a WC set. It employs a continuously rotating cheese, feeding a P.P.I. presentation. It was hoped that the splay of the beam in the vertical plane would be such as to achieve not only highly satisfactory surface warning results, but also air warning, so as to replace both 271 and 291 in the small ship.

A requirement arose, however, for a RADAR set which would give overall detection between 0° and 70° of elevation to a distance of 30,000 yards, for feeding into a Target Position Indicator in the Target Indicating Unit. To achieve this, the 293 was converted by tipping the cheese aerial up to an angle of 30°. This gave the necessary splay up to 70° in the vertical plane, but has a compensating loss in surface warning which is hardly acceptable.

Modern destroyers at present, therefore, are being fitted with 276, which gives quite good results on aircraft under 5,000 feet, and it is being backed up by keeping the 291 in the ship. This is, of course, far better except from the maintenance point of view. Work is being advanced on type 992 as the new Target Indicating set, of which there are no details yet.

The only other WC set under design is the 267W, which is being prepared for submarines. It will replace 291. This set is a form of hybrid, working on two wavelengths, approximately 1½ metres for Air Warning, and 3 cms for Surface Warning. They are being given separate aerial systems, the 3 cm. one being on a periscope mast. It is hoped that blind fire will be possible, using this set, with only the 3 cm. aerial showing above the water in day attacks. The two sets are not being designed to operate simultaneously. Both Class "A" and P.P.I. presentations will be used.

WS sets.

Several new WS sets are on the point of being brought into service. They are being fitted during the current year.

Firstly, type 276 has been produced to replace 272. It will, therefore, function instead of 277 in ships which cannot tolerate the topweight. New Fleet destroyers with the framework masts are being fitted now with 276, though this may be replaced by 293, as already stated. It has a power-rotated single cheese, which feeds a P.P.I. and "A" scan combined. It should give horizon range on surface targets, and 50,000 yards on aircraft below 5,000 feet.

Type 277 has been developed to replace both type 271 in small ships, and 273 in big ships. It has many advantages over its predecessors. It has a single power-rotated paraboloid feeding P.P.I's and "A" scan as required. It has greatly increased power which should give horizon range detection on surface targets, and 80,000 yards on aircraft below 5,000 feet. The aerial is stabilised in azimuth and elevation, and in addition can be elevated to 40° to measure height by angle of sight method on an H.P.I. This will be further discussed in Heightfinding. It is worth observing here that, if it is required to measure height it has to be done by sacrificing surface cover, for the aerial must be stopped and elevated.

Type 990 was begun in order to replace 277, but this is a long way off yet, and it has become involved in the design of a WCH set.

A small warning set called a 970 has been adapted from the R.A.F. H2S set used to assist bombing and navigation in bombers, for navigational use in landing craft. A P.P.I. presentation accompanies it.

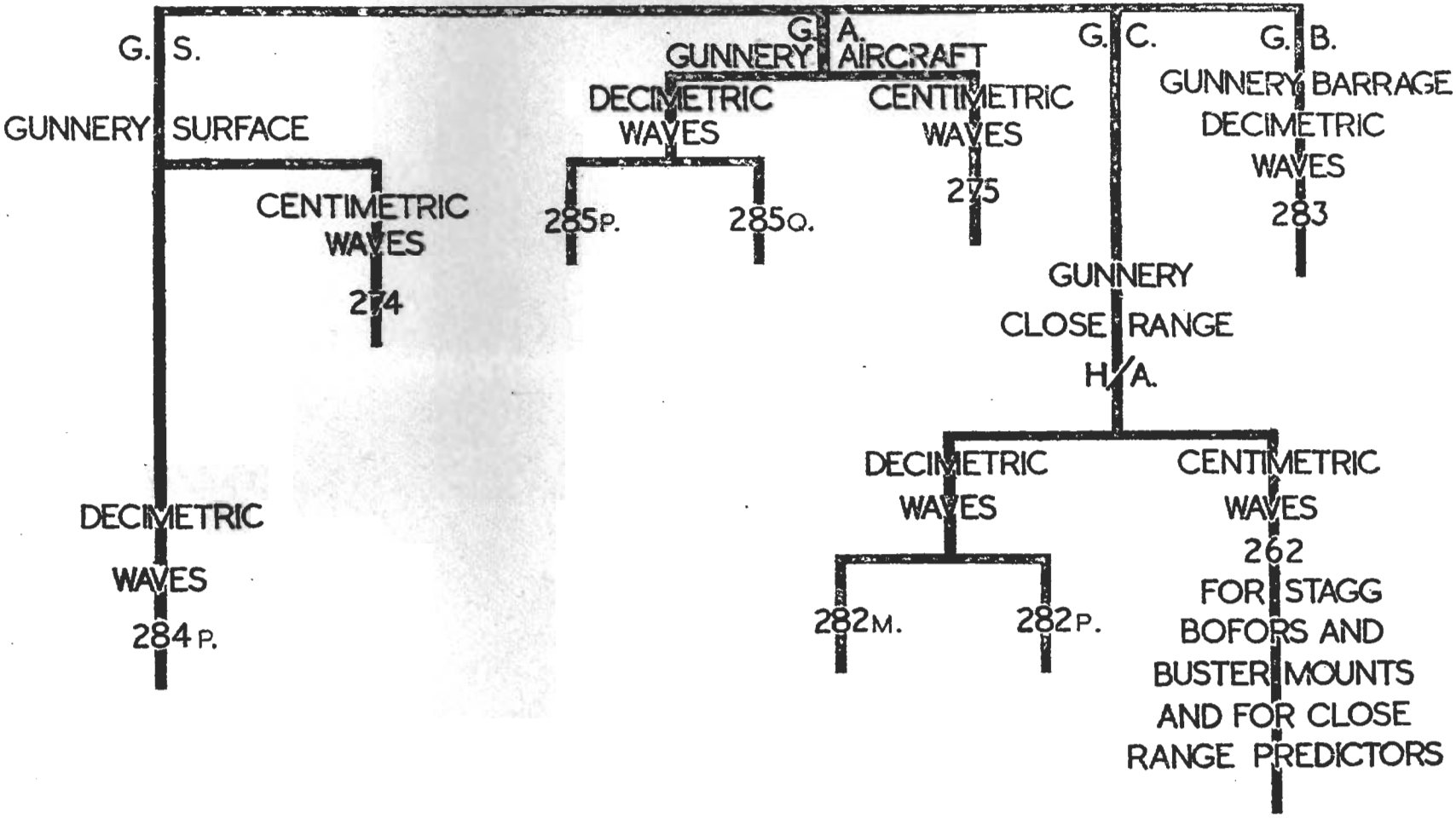
A new Surface Warning set for coastal craft is being developed in Canada operating on the X band. This is to be called 268, and should give reliable detection on another coastal craft at four miles.

WCH sets.

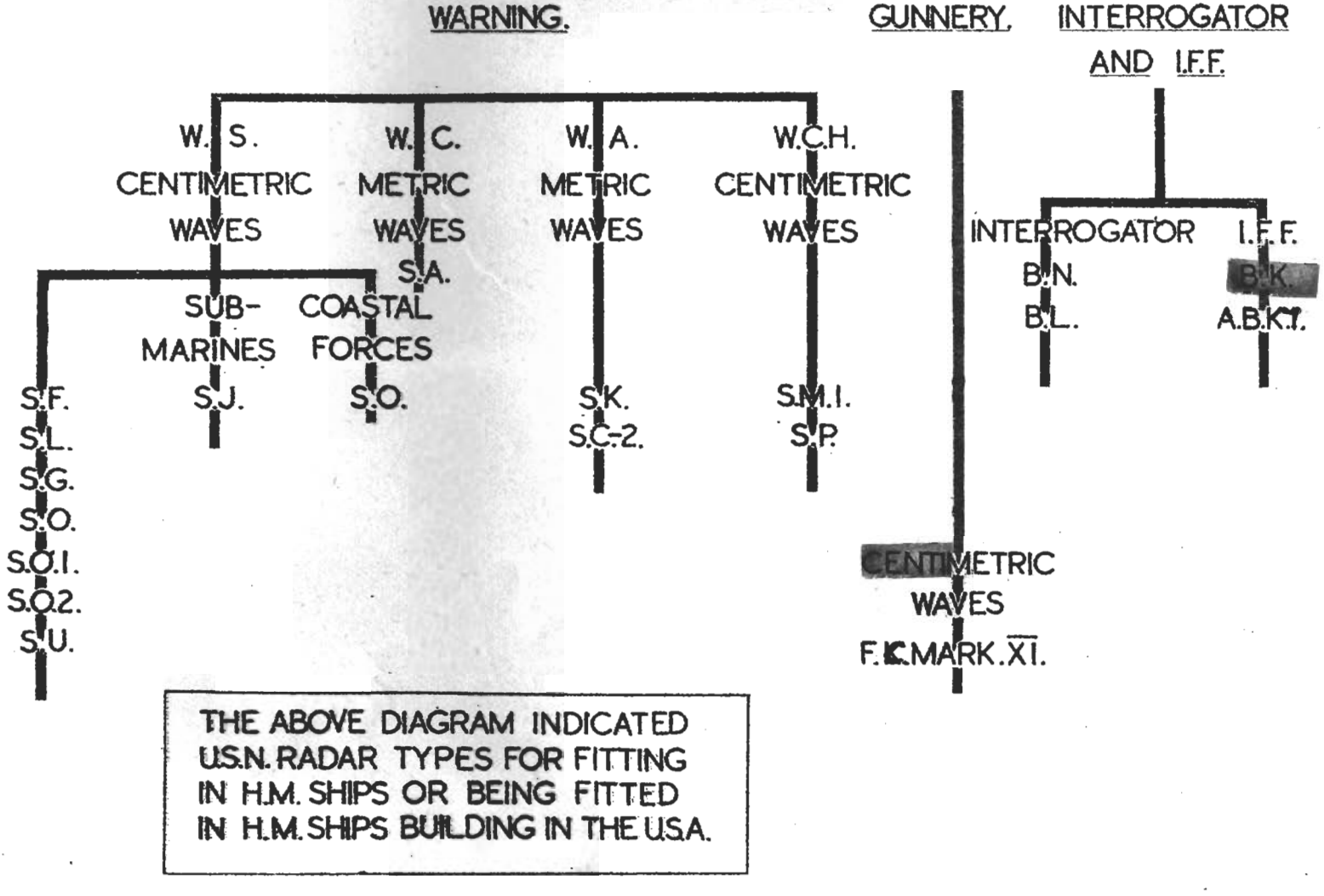
An entirely new class of set is now under development which is described as Warning combined with accurate Heightfinding (WCH). This was conceived on 10 cms. to give excellent surface warning and heightfinding by angle-of-sight method, with greatly increased range over 277; and also to get over the disadvantage of having to stop the rotation in order to measure height.

BRITISH SHIPBORNE FIRE CONTROL RADAR

THE GENERAL PICTURE



SHIPBORNE U.S.N. RADAR



THE ABOVE DIAGRAM INDICATED U.S.N. RADAR TYPES FOR FITTING IN H.M. SHIPS OR BEING FITTED IN H.M. SHIPS BUILDING IN THE U.S.A.

Type 294 was the first design, but it was rapidly replaced by tupe 295, which worked on four times the power at approximately 2,000 kilowatts. The aerial system was to be continuously rotating and power-driven - but this time with two sections - a horizontal cheese with a vertical cheese superimposed on top of it. The latter, which was for reception only, therefore elevated without affecting the horizontal or surface cover.

When taking heights, experience would probably show that for the initial height estimation it would be necessary to stop the sweep. The design of 295 has, however, proved so complicated the 295/960/990 combination is now being revised. In effect, a new 980 is being produced to give the continuous plan display of the 295, and a 981 to carry out the heightfinding function of 295 and alternatively the low cover function of 990. Types 294 and 295 have been dropped.

Gunnery sets.

The new GA and GS sets are also being designed on the 10 cm. wavelength.

Type 274 is replacing 283 as the main armament set for cruisers and above. It has a single cheese sited as before on the main director, and should give ± 25 yards ranging accuracy, and ± 3' of bearing accuracy - over ranges of 32,000 yards on a big ship, and 14,000 yards on a U-boat. Great hopes are set on this equipment that it will give accurate blind fire as well as greatly increased accuracy generally.

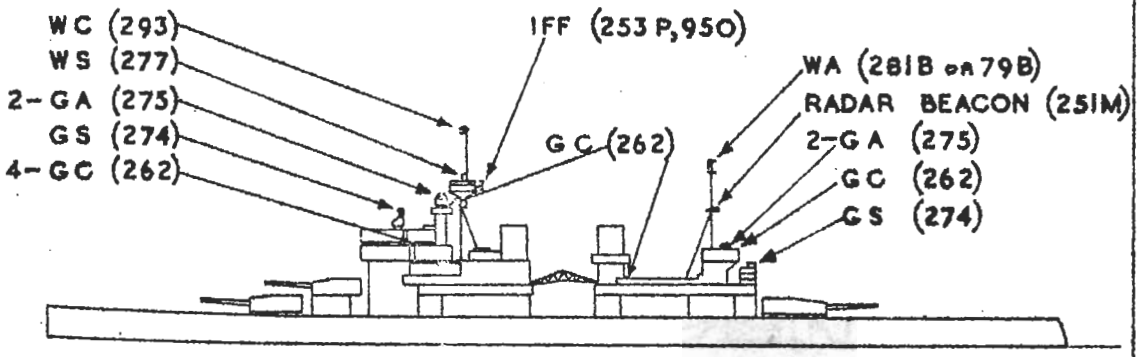
Type 275 is to replace 285 as the future GA set. The aerial system here consists of two bowls, or nacelles, not unlike car headlamps, which are fitted to the director. They are stabilised and can be elevated. The result is to provide range, line, and angle of sight, with a performance and accuracy equal to 274. The beam in this set is switched in the vertical plane as well as the horizontal to give accurate angle of sight measurement.

The only other Gunnery set being produced in the immediate future is type 262, a new GC set to replace 282. This works on a frequency of 3 cms, and is designed to give blind fire for close range weapons. After being given a lookout bearing, it scans automatically 15° either side in the horizontal plane and 50° in the elevation plane, moving in steps of 3° at a time. It takes 17 seconds for the whole cycle. When a target is detected the whole affair stops scanning, and automatically locks on to it. If there are more than one, it locks on to the nearest.

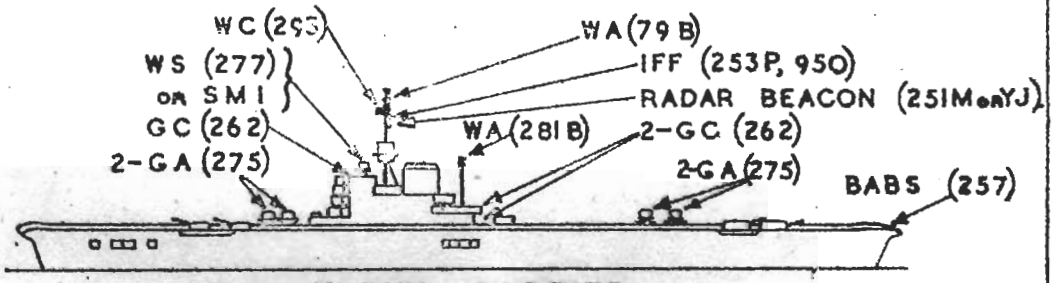
U.S. RADAR EQUIPMENT.

A tabulated family tree of U.S. shipborne RADAR has been prepared. The British equivalents have been put in alongside them so as to give an indication of their performance. All details of technique are pooled between our Navies, and we therefore progress together, and RADAR is equally developed on each side of the Atlantic.

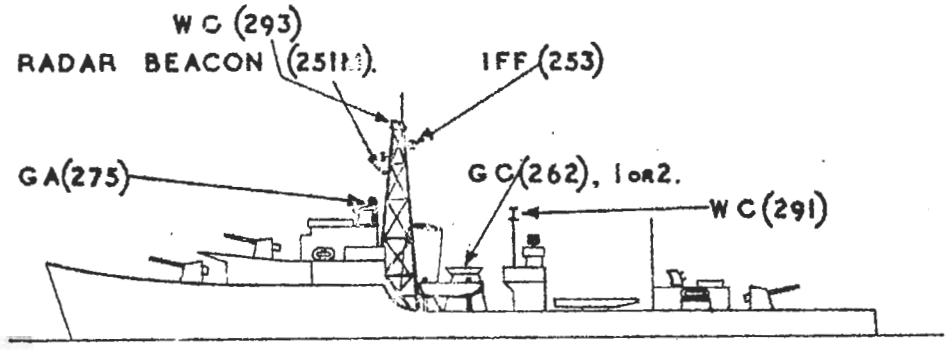
TYPICAL RADAR EQUIPMENT.
1945—6.



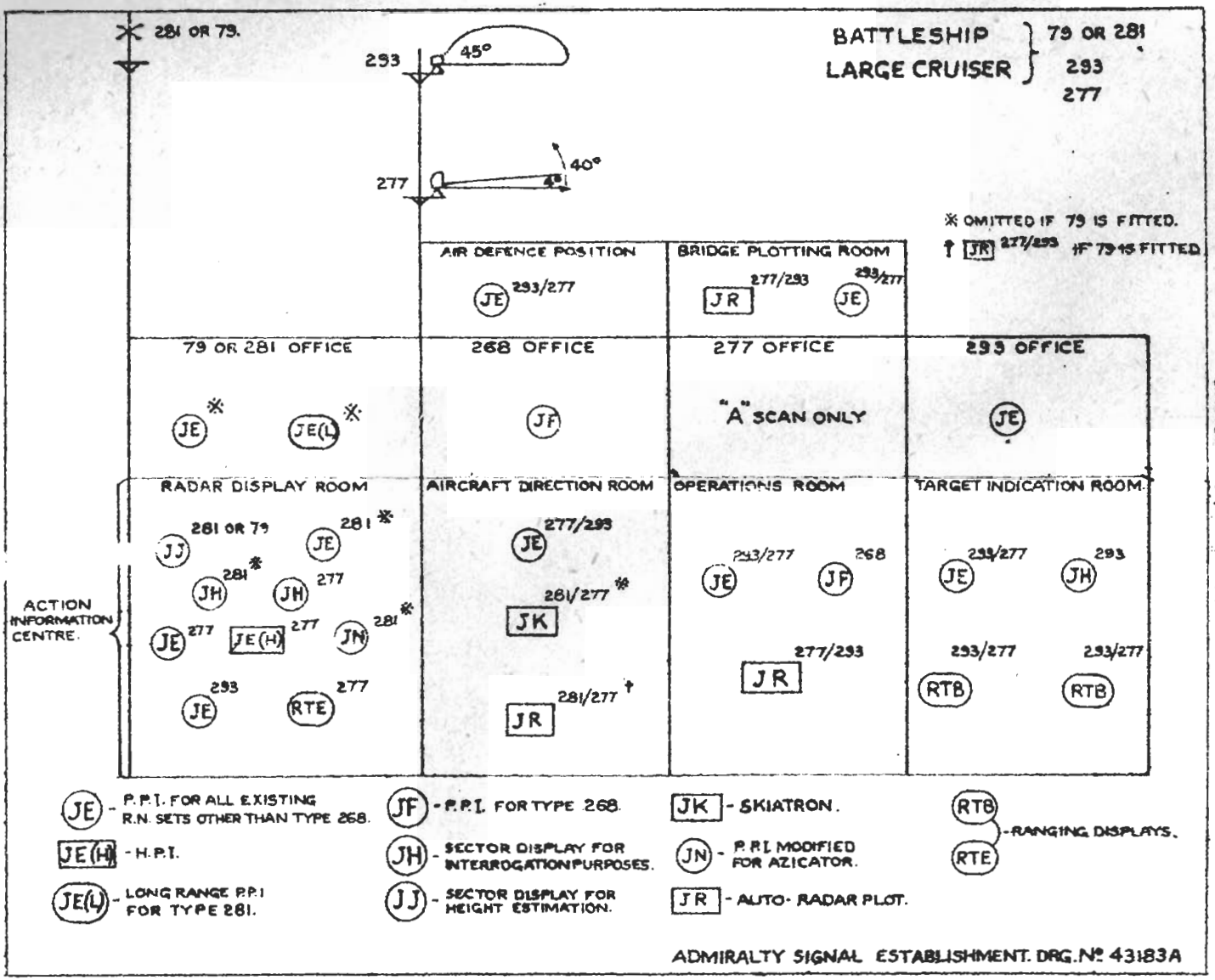
BATTLESHIP. (CRUISER SIMILAR).



FLEET CARRIER.
LIGHT FLEET CARRIER.



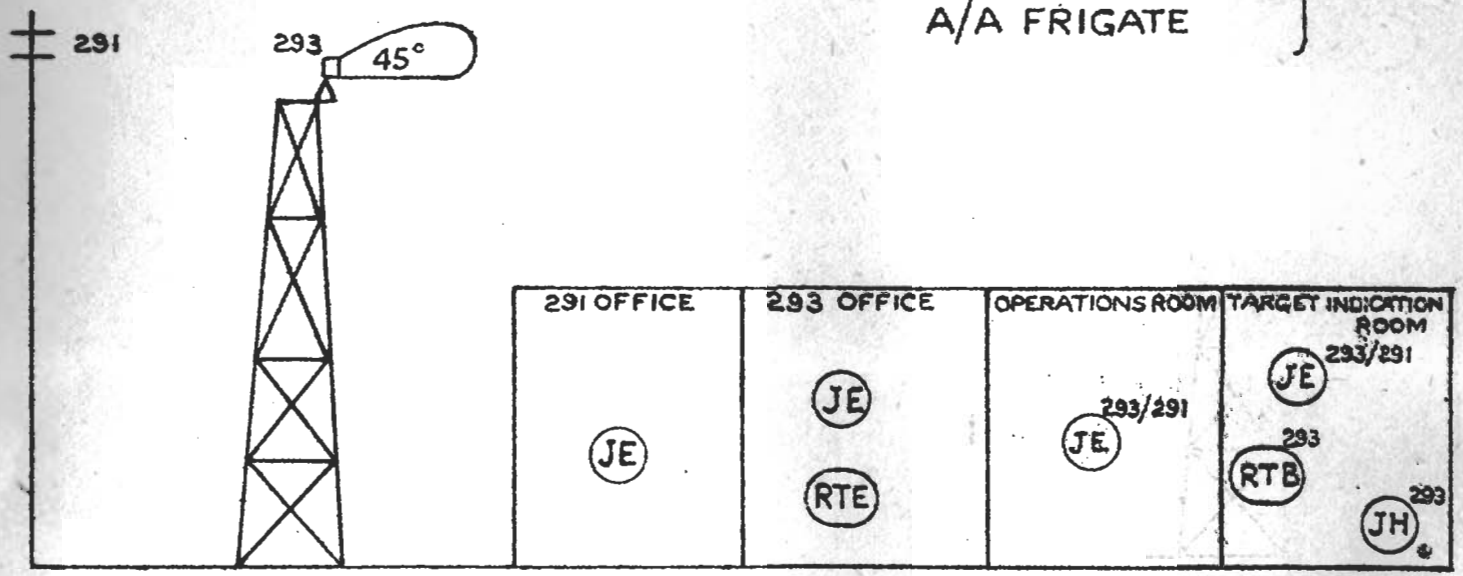
FLEET DESTROYER.



ADMIRALTY SIGNAL ESTABLISHMENT. DRG.Nº 43183A

C.A.F.O. DIAGRAM 9/45 (2)

FLEET DESTROYER
A/A SLOOP.
A/A FRIGATE
} 291 293



(JE) - P. P. I

(JH) - SECTOR DISPLAY FOR INTERROGATION PURFOSES.

(RTB) (RTE) - RANGING DISPLAYS.

ADMIRALTY SIGNAL ESTABLISHMENT. DRG.Nº. 43183E.