THE REQUIREMENT FOR RADAR CHARTS AT SEA

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At an Institute meeting held at the Royal Geographical Society on 17 June 1955, the following discussion took place on the extension of the navigational use of radar by either the production of special charts or by modifications to the existing ones. The President, Mr. D. H. Sadler, O.B.E., was in the chair. This subject has been discussed, indirectly, at a number of Institute meetings in the past, but a particular point was given to the present discussion by the publication, some time before it, of Admiralty Chart 1826, a chart of Burrow Head to Liverpool designed especially for use with radar.

The discussion was opened by Mr. L. S. Le Page who until recently was a member of the Operational Research Group of the Marine Division at the Ministry of Transport. He was followed by Lieutenant-Commander R. B. Michell, D.S.C., R.N., of H.M. School of Navigation and Direction (H.M.S. *Dryad*), and the last speaker to be called from the chair was Mr. R. F. Hansford of Decca Radar. Mr. Hansford was closely associated with the development of navigational shipborne radar whilst he was at the Admiralty Signal Establishment.

The views of the speakers should not necessarily be taken to represent those of the organizations they belong to.

MR. LE PAGE : In using radar the first problem to be solved is that of recognition and identification, for until an echo has been positively identified it is of no use to the navigator, except perhaps in giving him warning to keep clear. In the summer of 1947 I was privileged by the General Steam Navigation Company to make my first voyage with British commercial radar, on what I believe was the first British merchant vessel to be permanently fitted with such a set. I remember being impressed with the fact that the ship's master, Captain Painter, had considered it worth his while to make a series of sketches in white ink on black paper of his landfalls. Since then, radar manufacturers have from time to time produced and published radar photographs of important harbours and approaches on the world's trade routes, often in juxtaposition to a reproduction of the chart of the area, so that they may be of assistance to the navigator in using his radar. Such photographs are not of course comprehensive in scope, but they do indicate that more information is desirable on charts. I would suggest that with ordinary charts radar position fixing is only possible when the ship already has a very good idea of her position, or when the echoes arise from a particularly distinctive series of features. Further, there is a real risk of reading a false interpretation into a display. As Commander P. G. Satow has pointed out in a paper to the Institute, " Features which may have been charted for the original purpose of visual navigation are not necessarily those best suited to the radar method of fixing ".

There thus appears to be a *prima facie* case for the modification of charts to be of greater assistance to the radar user, and as I observe that in the Explanatory Statement on the Navy Estimates for 1955-6 it is stated that " Admiralty charts, of which there are 3600... are being modernized to match new methods of navigation

by radar and radio aids...", it would appear that there is some support for this viewpoint.

Opinions may differ as to the form the modernization should take, but I feel that there is a radar chart requirement on nearly every class of radar-fitted vessel. Admittedly for a vessel on a regular route, it is probable that an ordinary chart together with notes and sketches in a radar log will form a combination that no radar chart on its own can hope to excel. But this does not mean that such ships do not need radar charts ; some may not keep radar logs, for example, while on those that do the radar chart may considerably reduce the volume of paper work involved in radar log-keeping. Radar charts may again prove their worth when the ship is diverted to an unfamiliar area, or in emergency. Furthermore, there is the requirement for vessels of the Royal Navy whose duties compel them continually to vary their routes ; and for numbers of other itinerant vessels, such as fishing craft, salvage tugs, tramps, and so on.

If radar is introduced, it is in effect interposed between the navigator and reality, so that he has to interpret the picture which is the radar set's conception of reality. In doing so, the navigator is forced to abandon nearly all the means he unconsciously uses to identify objects which he can see directly — for example the colour, brightness, shape and size of small objects. He cannot readily pick out the echo due to a prominent visual landmark such as a mountain peak, whereas radar is completely indifferent to the fact that a lighthouse is transmitting a characteristic light of a million candle-power.

Radar of course scores nearly all its good marks in the map-like presentation which it gives, and this forms the major compensation. But there is an inevitable shift of emphasis from those features which are most evident to normal vision. A visual mark which is conspicuous is frequently denigrated by radar to being just one of a number of similar echoes, and the fact that it is labelled " Church " or " Windmill " on the chart is of no assistance to the radar user. Or there may be an isolated echo of land on the PPI, which it is impossible without auxiliary information to place. On the other hand, one often sees well-defined *groups* of echoes, perhaps from oil tanks or pylons, which by virtue of their regularity or characteristic layout are outstanding on the PPI, and these may arise from sources whcih are comparatively obscure to normal vision, and may not even be marked on the chart. Hence it is desirable that for radar use the solitary navigational mark should be abandoned in favour either of groups of marks (a fact that was recognized in the early attempts in the Thames Estuary to introduce patterns of buoys), or of extended targets such as coastlines, or, in effect, the new racons.

Since marine radar has no useful discrimination in the vertical plane, that is, it cannot distinguish between objects at different heights, indications of height on the chart are only of value if radar shadows and the radar horizon effect are utilized. Height contours have, however, formed the principal features of most experimental radar charts, and this is, therefore, a convenient point at which to examine the latest British " radar " chart.

That chart (Burrow Head to Liverpool, natural scale 1 : 200,000) shows high land in two colour layerings, light magenta from 200 ft. to 600 ft. and a darker shade of magenta for land over 600 ft. The coastline is slightly thicker than normal. Otherwise there do not appear to be any changes connected with radar navigation. In this area shipborne radar is probably of much more use for collision warning than for locating position, since there is such a concentration of other navigational aids —

radio beacons, the Decca Navigator system, Consol, Liverpool shore radar — so that a navigator may be expected to have a very shrewd idea of his position even in the thickest weather. Shipborne radar will give an extra degree of accuracy in fixing position relative to land at turning points, and in locating buoys, but it is most unlikely that the contours of land will be seriously appealed to for assistance in position fixing. Possibly a trawler making for Fleetwood would be helped by the appearance of long-distance echoes from the Lake District. Nevertheless the purpose of the experimental colouring is presumably less to enhance the value of this particular chart than to test opinion as to the likely merits of the changes introduced, for use on other charts. It is possible that for a ship maintaining a course 10 miles or more from land, the echoes obtained will fit the contours sufficiently well to give position from and along the coast ; this is a matter for practical experience. I rather tend to the opinion, however, that colour layering suffers from three main defects : it does not give enough detail, it gives the impression that height in itself is a source of strong echoes, and it does not give sufficient importance to slope.

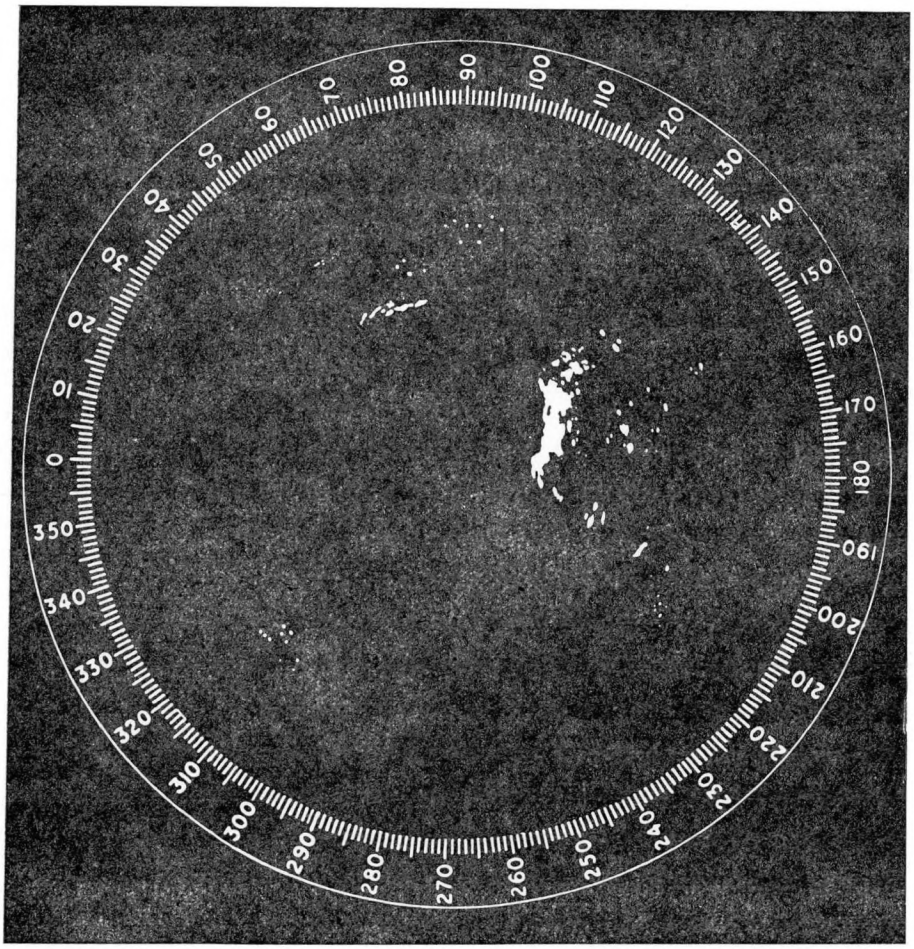

Fig. 1.
A part of the area covered by Chart 1386.
Certain inland peaks can be identified.

Fig. 1 is a PPI photograph taken on the 40-mile range-scale, of an area covered by the experimental chart. It does not seem to me that the charted contours are of much assistance in helping to fix position or even to identify outstanding echoes. On the other hand, the echoes appear in such distinctive patterns that emphasis of the sources of the principal ones would seem to be a desirable step.

It is noticeable that ideas tried out on previous experimental charts, for example the block shading of built-up areas, and the marking of selected targets as " Ra. Conspic. " have not been pursued on this chart. My impression is that very much more than the simple addition of widely-spaced contours is necessary if a chart is to be made fully suitable for radar. At this stage I shall therefore suggest what concrete alterations might be made to make such a chart suitable for use with radar.

I think the chart should set out to tell the mariner, first the manner in which the important navigational marks may be recognized as such when they appear as echoes on the radar screen, and secondly, that it should give some implied indication of their likely detection ranges. As a corollary I think it should also warn the mariner of areas where radar echoes are poor.

The selection of important navigational marks should be on the basis of practical experience, and it would be useful in this connection to consult the comprehensive collection of radar logs kept by many merchant vessels, in particular logs issued by the Radio Advisory Service, which were designed in part with the specific object of obtaining data for chart purposes.

Although contours at wide intervals may give little real idea of the character of the land, if these contours could be reinforced by others closely spaced in localized areas which are known or are likely to give good echoes, it would be a help to recognition ; the general level of echo strengths to be expected might be most simply indicated by the thickness of the contour lines.

Variations in the thickness of the coastline to indicate its echoing strength should be fairly pronounced, rather as illustrated in the example attributed to m.v. *Wairangi* in *The Use of Radar at Sea.*

The exclusive use of colour such as magenta for outlining or marking noteworthy radar features would seem to hold some promise, as it would attract attention in a manner clearly intended for the radar user. One might have such a coloured backing to a coastline, for example, or prominent groups of buildings could be coloured.

Certain targets such as radar reflectors might be marked with their effective heights and with some dimension that would give a clue to their radar response.

The possible use of charts with chart comparison units must be borne in mind and this may call for some desirable additions such as concentric rings on the chart for lining up with the range rings on the PPI when adjusting the scales to match.

It should not be difficult to devise a system of shading which embodies in its design both a guide to echo strength and also the direction in which the echoes will be received, and would also be suitable for use with a chart comparison unit.

Fig. 2 is a good radar photograph of the entrance to the River Mersey, showing unmistakable features ; too often, however, all that is visible, even at close range, is difficult to recognize.

In Fig. 4, a radar mosaic of historic interest is shown, made up in 1945 from photographs taken with naval 3-cm. equipment. Notice particularly the Essex coast;

Fig. 2.
Entrance to the River Mersey.

Fig. 3.
A modern PPI photograph of the Thames Estuary. Note the racon response on the Tongue light-vessel and absence of the boom defence shown on the mosaic.

Fig. 4.
A radar mosaic of SE. England, prepared in 1945.

the north coast of Kent with Herne Bay pier prominent ; and the north and south banks funnelling towards the Thames entrance. A recent photograph of these areas is shown in Fig. 3, taken with one of the latest commercial radars. In spite of the fact that these were taken ten years later, on a different ship, with a different set, and probably under different conditions, there can be no doubt that the echoes on the individual photographs can be recognized on the mosaic. These photographs seem to illustrate well the fact that radar echoes, like human faces, are characteristic and unique.

May I conclude these remarks by suggesting that charts of all scales should have radar features boldly, clearly and imaginatively marked, for I feel that we have yet to see a chart that goes more than a very short distance towards what a radar-modified chart should look like. Extensive operational research is perhaps the best method of establishing the value to the navigator of any changes or modifications which are made.

Lieutenant-Commander MICHELL : In all forms of positional navigation, dead reckoning is an important factor in the assessment of position. Radar navigation is no exception — especially when making a landfall. It is to assist the landfall situation as well as in coastal navigation that considerable effort has been made in the post-war period to design a chart that is suitable for both visual and radar interpretation.

Post-war mosaics from early navigational radar sets showing outlines of the Thames Estuary and the Scheldt showed the potentiality of radar interpretation direct from navigational charts. After trials and discussions, the first chart (Chart 2649) was prepared and issued by the Hydrographer in 1949 of the South-west Approaches to the Channel. This chart proved a major step forward in radar interpretation for landfall navigation and many navigators have been assisted by its use — particularly in respect of the detailed land contouring used in conjunction with a radar horizon range table. Through the use of this chart the Hydrographer received many comments by navigators sending in " marked-up " copies (for which a free new copy was returned — an offer that is still open). An analysis of these reports has led to the following notes on charts for use in radar navigation :

(*a*) The main objective is to make the *navigational* chart usable by radar navigators.

(*b*) So far the coastline has been made heavier and contours have been adopted in place of hachurings and form lines because this is the most accurate way of showing hill forms as well as being most economical in line work, thereby helping clarity of other detail on the chart.

(*c*) Contours, however, may need careful inspection for their interpretation and attention has been focused on overcoming this possible disadvantage for the radar user; layers have been accepted as the best method.

(*d*) Great care has gone into the selection of the present grey land (stipple) and blue shallow water (flat) to give a pleasing and therefore efficient effect to the navigational chart. This will be affected for the worse if large areas of land carry a layer over-print, especially if heavier shades become involved, by the use of more than two layers.

(*e*) Emphasis of the 200-foot contour is generally agreed as valuable but on heights above that opinions differ, and look like continuing to do so. If a special

chart were provided there could be three layers without much difficulty. In Chart 1826, the second layer is at 600 feet but, depending on the nature of the topography, it could be at 400 or 800 feet.

(*f*) Magenta provides a striking colour for outlining special radar features and may well therefore be used to mark the radar beacons now under development.

(*g*) The use made of topography by the average radar navigator is likely to be only on obvious targets, corresponding to his visual use of identifiable summits. The distance away and shape of the *coastline*, when in range, will be more used, comparable with the visual use of bearings to tangents of the land. The development of radar beacons, which will eventually be distinguishable from land echoes even when sited on the coast, will be an important advance for the users of radar and even an improvement on the (visual) use of lighthouses and lights.

(*h*) In the light of (*g*) and of the future development of racons, it might be asked whether the average mariner really needs coloured layering, which might mean an increased price of 1/6 per chart ?

It is probable that the Hydrographic Department would be averse to producing two versions of a navigational chart (one to be kept corrected for *Notices to Mariners*, &c.) and this would certainly be essential if more than two layers were desired with resultant increase in costs and prices. It is obviously possible for a user to shade for himself the contour or contours which his own experience shows to be useful.

It seems that the charts on which the chances of using topography for fixing may be likely to exist lie between the scales of 1/100,000 and 1/300,000 of which there are some 500-600 in the Admiralty series.

An appreciation from this summary led to the issue of a second chart (1826) — covering a high-density shipping area. This chart is more for coastal navigation than landfall and aims to assist the navigator to become familiar with PPI interpretation and chart contouring. The new chart emphasizes the two most important features — the coastline and the 200-ft. contour — for within 10 miles off-shore the coastline should be firm and well defined on the PPI whilst the 200-foot contour gives the 26 miles (landfall) detection range for a 50-foot aerial. Additional contours and spot heights are valuable in assessing the slope and inland features at various aspects. Contour lines are emphasized by magenta shading although, except in the case of the 200-foot contour, this it not considered essential. In fact, navigators may wish to shade in a selected contour suitable for landfall for their own particular set.

The marking " Ra. Conspic. " has been discontinued as reports from sea were inconsistent as to which objects were conspicuous at various aspects.

It is to be noted that a picture obtained from inland hills and mountains is unlikely to provide a position much better than within one or two miles and that it is not until a positively identified feature on the coastline appears that a precise position can be obtained. In this connection, it is most important to include spot heights on off-lying islands, thereby improving radar interpretation. In fact, this guidance in radar interpretation closely follows the visual equivalent where fixing by mountains, for example in Norway or southern Spain, seldom produces an accurate answer, though they provide a valuable guide, and it is not until shoreline objects of headlands, islands and lighthouses are identified that a reliable and accurate fix can be obtained.

However, apart from the chart there are other aids and devices that assist in radar navigation and may be briefly remarked on.

(*a*) The *Radar Station Pointer*, a transparent plotting sheet available as Chart 5028, provides a useful aid in landfall when the navigator records by range and bearing a number of conspicuous long-range radar echoes and fits them to the chart from the vicinity of his D.R. position.

(*b*) The *Chart Comparison Unit* whilst providing comparable accuracy does not confer any real advantage over existing methods when making landfall or when coasting.

(*c*) *Racons*. These provide most valuable aids to landfall identification and fixing. The policy of fitting racons is not known at the moment, but it is hoped that after the successful trials with the Tongue light-vessel racon further racons may be fitted to assist navigation.

(*d*) *PPI photographs*. Even with contoured charts identification is not always easy and experience gained during the past decade might help the mariner if it were incorporated by text and photographs in a hydrographic publication. Such a pamphlet might form a radar appendix to the Sailing Directions — thereby ensuring that the price of the basic book would not be affected for the non-radar fitted ship. Such a pamphlet giving landfall interpretation photographs for a 3-cm. commercial set at an aerial height of 50 feet on standard shipping routes and approaches to major ports would provide guidance in the same way that visual photographs are at present included in the Sailing Directions. A reference to the position of the photograph might be inserted on the chart.

(*e*) *Parallel Index*. Parallel lines inserted on a rotatable cursor on the face of the PPI provide the navigator with a simple, rapid and accurate assessment of many anti-collision and coastal navigation problems. Such problems as the closest point of approach of another vessel, to pass a given distance off a fixed mark, to turn to a predetermined line or to check the compass, may all be readily solved. These lines are now being inscribed on a number of commercial PPI masks.

The requirements for radar charts at sea must be studied in relation to the navigational value of the chart and its cost in production. Progress viewed in this light can then be assured of being in the right direction.

The author is grateful for the assistance of officers of the Admiralty Hydrographic Department in preparing these remarks ; the opinions expressed, however, in no way reflect Admiralty policy.

MR. HANSFORD : These notes will not attempt to produce a detailed specification for a radar chart but will rather review some of the main requirements and will pay particular attention to considering methods of using the information shown on the chart, in the belief that this may shed some light on the form which that information should take.

The existing large-scale pilotage charts already go a very long way towards meeting the radar assisted pilotage needs. Possibly the main requirements for this type of chart where there might be room for improvement are in the clarity of presenting the information and in the need to be able to view the charts readily in dim lighting. So far as coasting is concerned, the requirement is again reasonably well met, although some improvement in clarity of marking shore lines, built-up

areas and seaward marks could be of advantage, particularly to enable the charts to be viewed in dim light. In the case of charts which are intended to assist a radar landfall, the same requirements apply but it is here that the first major difficulties seem to arise. If the coastline on a particular chart is very steep there is no problem, since the radar picture obtained on board a vessel, even a long distance off-shore, will almost certainly present an unmistakable impression of the coastline. If there is a considerable depth of water off the shore the problem is again not likely to be very serious since, if the first echoes obtained on a vessel's radar are not easily identified, the vessel has the opportunity of proceeding closer inshore in safety until such time as an unmistakably identifiable coastline shows up on the radar screen. In some cases, however, where the shore is gently sloping and where there is a considerable stretch of shoal water off-shore, the vessel may find that only scattered echoes from inland features show on the radar when she is in a situation where it would be imprudent to approach any closer ; in this case, if the radar is to be used to assess the landfall it becomes necessary to identify the inland features. It is difficult to assess how often this situation arises and the discussion on the present papers may provide useful information here, but it can certainly be said that on the occasions when this problem does arise, it is a very serious one. This seems to be the most difficult of the radar chart problems to solve and accordingly the rest of these notes are devoted to this problem.

The problem in identifying distant radar features in the landfall case is chiefly to assess what land features are above the radar horizon and are thus capable of giving echoes ; ideally, an indication of the likelihood of echoes would also be presented but this desirable facility may very well be too difficult to meet.

An almost complete solution to the problem could be provided by using, instead of charts, a number of relief models of the coastline which could be immersed in a water tank and scanned with a small sonic radar which would present on a conventional-looking PPI a picture which should show a very close resemblance to the PPI picture of the actual radar set in a comparable position. Such a system could take account of the Earth's curvature, shadowing of one hill mass by another, slope of the land and built-up areas. It would even be possible to simulate non-standard propagation conditions by arranging different temperature layers in the water. In practice, of course, such a system is not likely to find any favour, both because of the very great cost of the system and because no navigator would wish to carry around a large number of three-dimensional models. The example, however, is of value because it indicates that if one wants a good answer it is necessary to employ a very elaborate system to provide it.

A fairly good solution could be provided by using a small television camera with a radial scan to inspect a chart which was layer-contoured with intensity shading for the various heights. A simulated PPI picture could be presented on a cathode-ray tube display and the associated circuits could take account of the Earth's curvature and heights of the land features ; a simple memory circuit would also allow due account to be taken of shadowing. Such a system could provide a very readily usable answer but its cost, of a few hundred pounds, would in all probability be prohibitive. An equally good but slower answer could be provided by the calculating instrument invented by Gold in 1943. This instrument was designed to be pinned to the chart at the assumed D.R. position and included a small pointer which, when run out radially from the D.R. position, carried a scale which indicated the height required to appear above the horizon at that range ; a radial pencil line was drawn through any land mass whose height contour exceeded the reading on the scale. A

mechanism in the instrument also stored the greatest height crossed in order to assess the possibility of shadowing on more distant masses. A number of traverses along several radials permitted an overall picture to be built up in the course of five or ten minutes.

A quick and simple aid to recognition could be devised by using a transparent disc with the transparency graded from completely transparent at the centre to opaque at the circumference, and placing this over a layer-contoured chart with its centre on the assumed D.R. position. In this way all land features at close range would be seen readily through the transparent region of the disc while only high land with very intense colouring would show through the more opaque regions at longer range. Such a device might be useful for obtaining a very quick rough impression but it would have the disadvantage that it could not take any account of aerial height, and it also would probably be necessary to employ a white-on-black presentation for the chart. A more practical solution would be to print at the side of each chart a strip with coloured gradations identical with those used on the chart, spaced out at distances corresponding to the ranges at which each height-layer would appear above the horizon ; measured back from zero of this strip could be printed various scanner heights marked off at the correct distance corresponding to the horizon range from the scanner. Such a strip could be cut from the chart and pinned down through the appropriate scanner height onto the assumed D.R. position as shown in Plate I. Then, when this strip was laid across any land features it would merely be necessary to observe where any layer intensity on the chart exceeded the intensity of colouring on the strip in order to determine that this section of land was above the horizon ; the strip could readily be swung round the D.R. position to build up a complete impression. By printing the strip directly on the chart an aid of the correct scale could be provided with each chart. The system should be cheap to produce, easy to use and, should be of considerable practical assistance.

At the bottom end of the list of solutions are the " rough and ready " methods. Here, either the problem must be solved by the navigator doing a considerable number of evaluations of $1\text{-}2\sqrt{h}$, or, alternatively, he must press on, happy in the belief that a quick look at the screen and a quick look at the chart will provide him with all the information he needs. At present it would seem that all the practical work of this nature at sea falls into the rough-and-ready category. While it is most unlikely that it is worth while going to the elaborate schemes proposed above, it would certainly seem that there is a strong case for using methods somewhat between the two extremes. It should be noted that, of the proposals made above, with the exception of the most elaborate, all can be applied to layer-contoured charts.

It is my opinion that if all charts were produced with clarity in mind, if landfall charts showed layer contouring and if some aid to the ready employment of the latter were provided, the mariner's task could be considerably eased.

DISCUSSION

The three contributions printed above were then discussed by the meeting as follows.

Captain A.R. PERRY SHAW (Master Mariner) : I suggest that the illustration of radar views in the pilot would not be much use, as the same part of the coast, pictured from a very slightly different angle, would be entirely different. I was quite interested to hear that that first chart of the south-west part of the channel had

been revised on information sent back to the Hydrographer. I would like to make a suggestion that if the Hydrographic office considers issuing further charts, they should request that shipmasters should send in the particular part where they wish to have a new chart, marking salient features.

MR. A. L. P. MILWRIGHT (Royal Naval Scientific Service) : All the speakers this evening have agreed that when you are within ten miles or so of the coast, the pictures you get on the radar of the coastline itself are quite adequate to enable you to identify your position, except in a few cases where the coast has no identifiable features. I do not agree, however, with the suggestion that you should fix your position at landfall by radar using high ground inland. What does the mariner do in clear visibility conditions ? Does he, in fact, ever take high ground inland to fix his position ? He, I know, takes bearings of well-charted positions such as lighthouses. In the radar case, accurately charted positions of radar beacons would provide the same answer and fewer beacons would be required than objects in the visual case since a single radar beacon gives both range and bearing. You should be able to identify your position with radar beacons without all this complication of indicating rather difficult objects inland which vary with aspect. Radar beacons will not vary with their aspect.

Lieutenant-Commander H. KNOLLYS (H.M.S. *Dryad*): I think that the mariner does undoubtedly use conspicuous features inland if they are available. There may be a greater or lesser difficulty in identifying them, but I am not sure that that is entirely relevant. I think the point is rather that there is a need for some positive indication on a radar inconspicuous coast by any possible means. We did recommend that this problem of sectoring high-land contours by colours and so on should be pursued, for areas where it is not envisaged that radar beacons would be situated. We have little information about what effort is available for placing radar beacons round the coast ; but we are much inclined to feel that if radar beacons are going to be available, they will provide the solution, so that any other research will only be needed for areas where they will not be placed.

Captain K. St. B. COLLINS (Hydrographer of the Navy) : I would first of all like to say that I think the speakers this evening gave us a brilliant exposition of the situation as it stands with regard to the adaptation of a chart to enable the navigator to make the most of his radar set. There is not very much more for the rest of us to say, but I was hoping that when I was introduced as the Head of the Admiralty Department concerned, you would all get at me and tell me where this particular chart falls short.

I quite realize that we have got a very long way to go. Our attitude has so far been that every radar object is a physical feature of some sort, a brow of a hill or maybe a house, and that provided the Admiralty chart shows all physical features in some way, it meets the need of radar ; and the only outstanding question is the emphasis you give to one feature and the reduction of emphasis you place on another. The chart shown tonight is a bad example of adapting a chart for radar because by the time you get onto that chart you are probably not using radar as your sole navigational instrument ; you will be using Decca and perhaps visual bearings as well. But on an approach chart, radar may be the only tool you can use, coupled of course with your D.R. It is, therefore, only on the approach charts that the problem really arises. I think that in the case of coastwise charts, the problem is merely one of

making the chart show as much coastal detail from the ordnance sheet and the hydrographic sheet as can be done cartographically with clarity. The approach is a different matter and I think that, with radar beacons or without, the more powerful radar gets the more it will be necessary to give prominence to inland features. At present, I think that 30 or 40 miles is as much as we are asked to deal with, but I can visualize radar sets made higher and stronger — like everything else these days — and the problem may become a very difficult one. I am not entirely satisfied that the showing of contours is all that is required. I have just come from sea myself, from the West Indies, and you who know Jamaica, will agree with me that such abundance of high land makes the identification of radar echoes more difficult and not easier, and the accurate fixing of a landfall by radar almost impossible. The curious part about Jamaica it that I have never, on two successive occasions approaching from the same bearing, got a recognizably identical picture. In that connection I would like to say that this question of PPI pictures is a very difficult one. I think there may be something to be said in favour of PPI pictures, and I realize that my Department has been accused of a lack of enthusiasm to follow up the subject in the past. I would like to take this opportunity to encourage navigators, and also the experts with us here tonight, to send in pictures for us to see, and if we find quite definitely that they do have a resemblance from all angles of approach on some particular feature, I think it would be worthwhile finding some method of publishing them either in book form or on a chart. I think it is one of the most promising lines of enquiry that has come out of the discussion tonight.

Captain R.A. BURROWS (Senior Nautical Surveyor) : On many of the older Admiralty charts small sketches of the coastline showing prominent features were shown. Would it not be possible to include on the margin of charts a black and white silhouette of the coastline showing high land behind as it would seem to a mariner on radar at, say, ten miles distant from certain selected positions on normal shipping routes along the coastline ?

MR. LE PAGE : I believe that the Radio Advisory Service has a great deal of relevant information as to what use the mariner makes of inland echoes, and which echoes he uses for his fixes. The Service has collected radar logs from all over the world which tell which echoes are used by the mariner, at what ranges these echoes are detected, and the mariner's opinion of the value of these echoes. Perhaps the two members of the Radio Advisory Service who are present will allow us to have a brief summary of their findings on this subject.

Captain R. G. SWALLOW (Radio Advisory Service) : I am afraid that I cannot give all the answers without looking up details. But I would like to give my view about what radar information should be given on charts. As far as the large-scale charts are concerned, my view is that they should have marked on them racons, ramarks, and any object such as a buoy which has a radar reflector on it. But I do not think it is necessary to mark in any great detail, or in colour, the contours on the land because the coastline will clearly be seen on the PPI and it will not be necessary to know what the inland details are. As far as the small-scale charts are concerned, such as can be used for landfall, I agree entirely with what Lieutenant-Commander Michell says — that the navigator in a ship which has a 50-foot aerial will want to detect the coastline at about 25 miles. What may be seen is anything that is above 200 feet and therefore I entirely agree that 200 really is the bottom contour required. If you look at a large amount of the land in the British Isles you find that everything above, say, 200 feet is well

inland except in a few isolated places. If the high ground is well inland you will not get it on your radar at all if you switch on 20 to 25 miles away from the coast because it will be too far away, and the majority of the hills that you will see are between, say, 200 and 700 feet. Therefore we are in agreement with the plan to put the 600-foot contour on the chart, in another colour. But we would like also to see the 400-foot contour printed in, the reason being that what is required is to tell how much echo you are likely to get from any particular coast you are approaching, and that will depend largely on the steepness of the slope. If you have the 400-foot contour marked you will be able to see whether the land is steep between 200 and 400, or alternatively steep between 400 and 600. If in fact the slope is gradual, you may not see it at all on your radar.

Mr. D. DEACON (Radio Advisory Service) : We have analysed a large number of radar operational logs from ships in all parts of the world; these show that the mariner, in using radar to make a landfall, picks out the recognizable features from his radar display. These include an identifiable coastline, a sea mark, or some radar conspicuous target on shore. In the main, I would say there are few inland targets which can be used with certainty and these are not more than three to five miles inland. It is his distance from shore and danger which concerns the mariner most, and not his distance from a high hill several miles inland.

The superimposed slides we saw earlier of a ship in a certain chart position receiving radar echoes from high ground inland, and the completely different radar picture some while later when the ship had moved to a new position were not encouraging. Lieutenant-Commander Michell himself said, « what is conspicuous to one is not to another » and I think this clearly emphasizes, together with the slides, the difficulty of creating a permanent means of identification from this type of target. It would seem that the whole problem of emphasizing the high land well in from the coast needs further investigation.

Lieutenant-Commander MICHELL : Although the PPI picture does, of course, change with aspect, and so position, the main shipping routes past any particular headland are reasonably consistent. Therefore it should be possible to select suitable points on the route, say about 25 miles off-shore, for which « radar views » could be given in the Sailing Directions.

Captain E. G. IRVING (Assistant Hydrographer) : I would like first to mention the question of the racon. That, of course, we will symbolize on the chart and it being a conspicuous object a conspicuous symbol will have to be thought out and adopted. I think we shall have to go to the International Hydrographic Bureau to get agreement, but nevertheless we shall do it. The second point brought up by Lieutenant-Commander Michell was the radar horizon table. The table as shown on 2649, was left off 1826 for the simple reason that 1826 is not a landfall chart. Mr. Hansford's very ingenious strip-cartoon is good for a limited purpose, but you obviously do not want to use the horizon range when you are close in, but on 2649 it would be useful and it would be useful, of course, to get the high land behind. Thirdly, Captain Swallow mentions the 400-foot contour; I hope that Mr. Atherton, the Chief Civil Hydrographic Officer, will enlarge on cartographic problems, but we must not clutter up the chart too much with too many extraneous details. The coastal strip, suggested by Captain Burrows, would be extremely difficult to portray.

With a coastal chart such as this one, the coastline you would first see would usually be 10 to 12 miles off, with a 50-foot aerial. At 10 miles you have got, shall we say, at least half-an-hour before you run into danger under normal conditions, and I think you could fix yourself by radar ranges and bearings of the coastline with reasonable accuracy before then. I do not think it necessary again to clutter up the chart with silhouettes and all these things; it means more work, correcting where required, and so should be left off.

Mr. HANSFORD: I would just like to make one point, on this question of the use of inland information for position fixing. I completely agree with Captain Irving that no one is really concerned with rapid use of inland information on the particular chart we have considered. The problem only arises in the case of making a landfall. I would say that inland information is probably used extremely little by the radar navigator. There are perhaps two reasons for that. First of all, for a long time we have concentrated on the development of radar sets giving very high definition pictures at close range and only with the solution of that problem have we paid more and more attention to development of radars of higher performance and longer range, which are capable of picking up land masses at ranges of anything between 30 and 50 miles. Four or five years ago in commercial radar that was impracticable; today it is happening very frequently. Consequently, I feel that the number of cases when one does pick up high inland features will increase as the use of the latest radars becomes more common. Surely, the other reason why not much use is being made of inland fixing is because it is at present extremely difficult to sort out from the chart what high land can show up and what can not. I feel that if we can go some way towards easing this situation, at the same time as providing the longer range sets, then the use of inland fixes will increase.

Mr. M. ATHERTON (Chief Civil Hydrographic Officer): I speak as a representative of the civilian staff in the Admiralty Hydrographic Department whose job it is to compile charts. Generally speaking, it can be said that we in this branch of the Department do what we are told to do. It is our business to meet the requirements of the mariner if it is possible to do so, making use of all the information available to us. Now it is when, as so often happens, requirements are not defined as in the present case, that the compiler feels it necessary to study some aspects of the problem himself to see if he can devise a chart or diagram which will serve as many mariners as possible.

For the purpose of all discussions I have read so far and, in fact, in my own thinking, I have assumed that we are all agreed that one chart must be made to serve the needs of both visual and radar navigation. I think that if a different view is taken it will be necessary to show that the production of two separate versions is economically possible. We, as a Department, would have to be convinced, for instance, that all mariners would be prepared to spend, say, about double the amount on chart cover for an area. I will talk then on the assumption that we need one version to serve both for visual and radar navigation, and perhaps one or two observations about the production of an ordinary navigational chart will be relevant; and from these we may be able to see how the chart can be adapted if necessary to the requirements of radar.

One of the most important considerations in the production of charts is that, unlike maps, it is necessary to limit the number of colours as much as possible.

There are two main reasons for this:

(1) The chart must be legible under an amber or even red light.

(2) An Admiralty chart is always maintained in a correct state for navigational aids and dangers by the correction, first of zinc plates before printing and secondly of stock copies after printing.

It has been found from experience that the maximum number of printing zincs for each chart should be fixed at three, save, of course, for exceptional cases which must always arise. These colours are black, light blue and magenta. Another important consideration is the fact that it is desirable to show as much work on the basic black plate as possible. There are also two main reasons for this.

(1) Frequent small printing runs, which are necessary to save much hand correction, require, coupled with the correction of the zinc plates themselves, fairly frequent replacement of these plates from the master drawings. When this happens, it is usually preferable to replace the colour plates as well. The whole operation is much simplified if the colour plates are merely used to accentuate detail rather than include essential basic information.

(2) The second reason is that this procedure makes for accuracy.

Now let us consider how these methods of preparation of chart plates affect their adaptation for radar purposes. Take, for example, contours. These lines, in common with the basic information on a chart appear on the black plate. The only alternative is that they should be on the magenta plate, but this is not practicable for reasons I have already given. Map compilers will view with horror any suggestion that elaborate contours should be shown on the black plate and I quite agree. Admittedly, charts cannot show elaborate contouring, and in practice, so as not to conflict with other detail, the number of contour lines must be limited and also must to some extent be smoothed out.

Let us consider the effect this has on the value of a chart for radar purposes. It means that well-defined slopes which may give a good radar echo will not necessarily be well shown on a chart. On the other hand, of course, the chart can show the *general* underlined trend of, say, the 200-foot line. Realizing the limitations of the contouring of a chart, I think that something could be done to indicate slopes that are known from practical experience to give good echoes at several ranges and different bearings. I see little point in marking specially an area which only gives an echo at a selected range or bearing. The chart would merely become a confusion of captions and legends and hardly intelligible to anybody.

Here I would like to ask a question of the practical navigator who is an enthusiast for radar. Supposing we could insert accurate contouring on charts coupled with some form of layering to facilitate its interpretation, would the navigator be able to use this to provide an accurate fix or would it merely be of interest to him so that he could say « such and such a painted area on the screen must be accounted for by contours in that vicinity, &c. » I do not think it would be right to go to a lot of expense and trouble to provide something which is merely of interest.

I am told that the most conspicuous feature on the radar screen is the coastline and we have taken steps to accentuate this on all charts. After the coastline, I understand that radar conspicuous buoys and beacons become important and I do not think I am speaking out of turn by saying that we are prepared to accentuate these in some way. Lastly, any conspicuous parts of the topographical detail that are known from experience to give good prominent echoes generally can be shown.

Having said that, I have no authority to commit the Department any further at this stage although, of course, we will continue to interest ourselves in all developments in this and other forms of navigation. In conclusion, I would like to say that radar is, of course, only one new form of navigation; it will be appreciated how difficult it would be to produce a separate type of chart for each new form. It will perhaps be seen how important it is to adhere to one form of chart for all purposes.

Captain SWALLOW: In our view the part of the coastline that really is going to affect anybody making a landfall is between about 200 and 600 feet, and I would like to say that it is our very strong view that to include the 400-foot contour will not by any means be an extraneous detail.

Captain IRVING: It has just been pointed out to me that the 400-foot contour is, of course, marked on Chart 1826.

Commander J. M. SHARPEY-SCHAFER: There are some, though not many, parts of the world where fixes from well inland are necessary. The Palawan Passage in the China Sea is one where a great many accidents occur to shipping, where there are reefs 25 miles off land and high land beyond, with a passage about 25 to 30 miles wide. The probability is that with a 25-mile wide channel to go through, even the roughest of fixes on charts should be sufficient with the radar. In other parts, like the Great Barrier Reef, where the passages are so narrow, you have got to be much more accurate than the $\pm$ 1 mile of radar fixes from topography. Any navigation you can get off contours is, I believe, only accurate to a mile and very rarely down to half a mile. Is it not perhaps the case that the mariner is quite content to wait for an accurate position when the coastline shows at about 10 miles? Radar topography fixing does require some form of chart comparison, if only by tracing or protracting, to make any sense and this method simply has not caught on as an important need or as particularly useful at sea. As to radar views in Sailing Directions for recognition, when one has the radar picture at sea there is so little difficulty in recognizing it, that only rarely would radar views be justified or used. One such rarity might be in deciding whether the radio masts or the minarets show first about 25 miles off Alexandria.

Chief Officer P. A. THOMPSON (Shell Tankers): Where more positive types of identification, such as radar or radio beacons, are available, surely the extensive marking of charts with additional information is going to make for greater difficulties of reading the chart when time is short and loss of « night vison » can be important.

I feel that where we need some additional charted information., whether in the form of notes or sketches, is in some of the more sparsely charted areas of the world. I have in mind the southern coast of Arabia. Areas such as this with a low foreshore and mountains inland often provide echoes not easily given positive identity, particularly when ships are passing a distance of 15-20 miles off as is common enough during the south-west monsoon type of weather.

Mr. Milwright has asked whether mountain tops and similar inland marks are used for navigational purposes by means of visual bearings. To some extent they are; after all, in many places we have little else to choose from, and an approximate " fix " used with caution, is much better than none at all.

Captain COLLINS : When one draws a chart one can only use the best material available. In England, for instance, we can get first-class maps and, in theory, it would be possible to put contours down to about 25 feet or something of that sort. But in Arabia, to take one example, not only are there very few maps but those that exist do not agree. If you look at the very few maps obtainable and compare them one with another, you will find that the hill work is not in the same place on any two, so that when we come to compile the chart we dare only show a generalization of the contourings, which will convey to the radar navigator that he must not expect to fix himself with any degree of certainty by hill work alone. So you see that one of the troubles of this radar navigation, which until the last speaker arose had not been mentioned tonight, is that it is essential to have available accurate and detailed information before you can draw a chart to meet radar requirements fully; and in many parts of the world the data inshore are so sparse that this is not possible.

Captain H. TOPLEY (Ministry of Transport) : We must have one chart that will do for clear weather and for radar-navigation. Now, although a town looks very different on radar from its visual appearance, if you are going to mark the chart with what the town looks like on the radar, it will not be much use for ordinary straightforward navigation in clear weather, and we have got to remember that in most parts of the world for only one or two per cent of the time do you use radar. I like Mr. Hansford's little strip which is very ingenious, and if I was in that spot I would love to know that I could see the Isle of Man on the radar if I was lucky; the only thing is that if I knew I was there I would not want to see the thing at all; it is only when I do not know where I am that I want to see something. There are a great many parts of the world where you cannot approach the coast to pick up the accuracy you want with radar on the coastline itself, but the majority of these places will have some other aid for navigation. I am afraid I am not very happy about contouring anyway. If it can be done it might be some help, but I think a chart would be spoilt by a lot of contours on it, to be used only once in a hundred times.

Mr. D. O. FRASER (English Electric Company) : I am being intrepid in joining in because I have nothing to do with marine navigation. One suggestion that appeared to me valuable was that of showing the appearance of the radar picture of the coastline at certain points along shipping routes. I wonder whether it would be possible, say for every 20 or 30 miles at, say, 10 miles off the coast, to enclose in a small circle on the chart, perhaps $\frac{1}{2}$ inch or an inch in diameter, a black and white representation of what the radar picture would look like at that point of the coastline, based on a fairly standard radar equipment.

Captain COLLINS : I congratulate Mr. Fraser, who claims he does not know anything about the sea, for putting forward a very good suggestion for navigating on it. If on a trade route we could get a few PPI pictures actually on the main shipping lane, it might be worthwhile reproducing them in some manner. I doubt if it would be a good idea to put them on the chart in little circles as suggested, because this might hide detail underneath, and it is possible that there would come a time when you might hide the symbol for a dangerous wreck or something of that sort. I think it would be a rather dangerous thing to introduce on charts. That is the only criticism I have; otherwise I think there is something to be said for it. I would prefer to take the little circles off the chart and put them, perhaps, in a a route handbook. If we find that these pictures are reasonably constant, and therefore useful, I shall look into this matter very closely. I might suggest that we supply

PPI photographs in booklet form, provided that it can be done without costing too much. We have virtually a monopoly in chart production and we have heard a good deal lately about the evils of that in another place; it is therefore up to me to keep prices as low as possible so that those who go to sea can afford all that the Hydrographic Deparment offers.

The CHAIRMAN: The time has come when I must bring this most interesting discussion to a close. I hope the Hydrographer of the Navy has found this discussion of assistance because, as he has just said, he is ultimately responsible for chart production, and criticisms or suggestions or suggestions must be directed to him.

The title of this evening's discussion was " The requirement for radar charts at sea ", and although I cannot hope here to summarize the discussion, it seems to me that two things have emerged very clearly: that it is most desirable that there should be a single chart to serve both purposes and that both the ordinary geographical features and those special features which are capable of giving a radar echo, should be clearly marked on the chart. That leaves outstanding the question whether the chart will then show, perhaps helped by some device such as Mr. Hansford described, what echoes might actually show on the PPI; but it will not indicate what echoes will in fact show. This would seem only to be possible by means of a large series of actual photographs, or diagrams, of the echoes shown on commercial radar screens. I am sure that this discussion has served a useful purpose and that it will, in due course, be reflected in Admiralty charts.