DANGEROUS WRECKS IN THE SOUTHERN NORTH SEA
METHODS OF SEARCH

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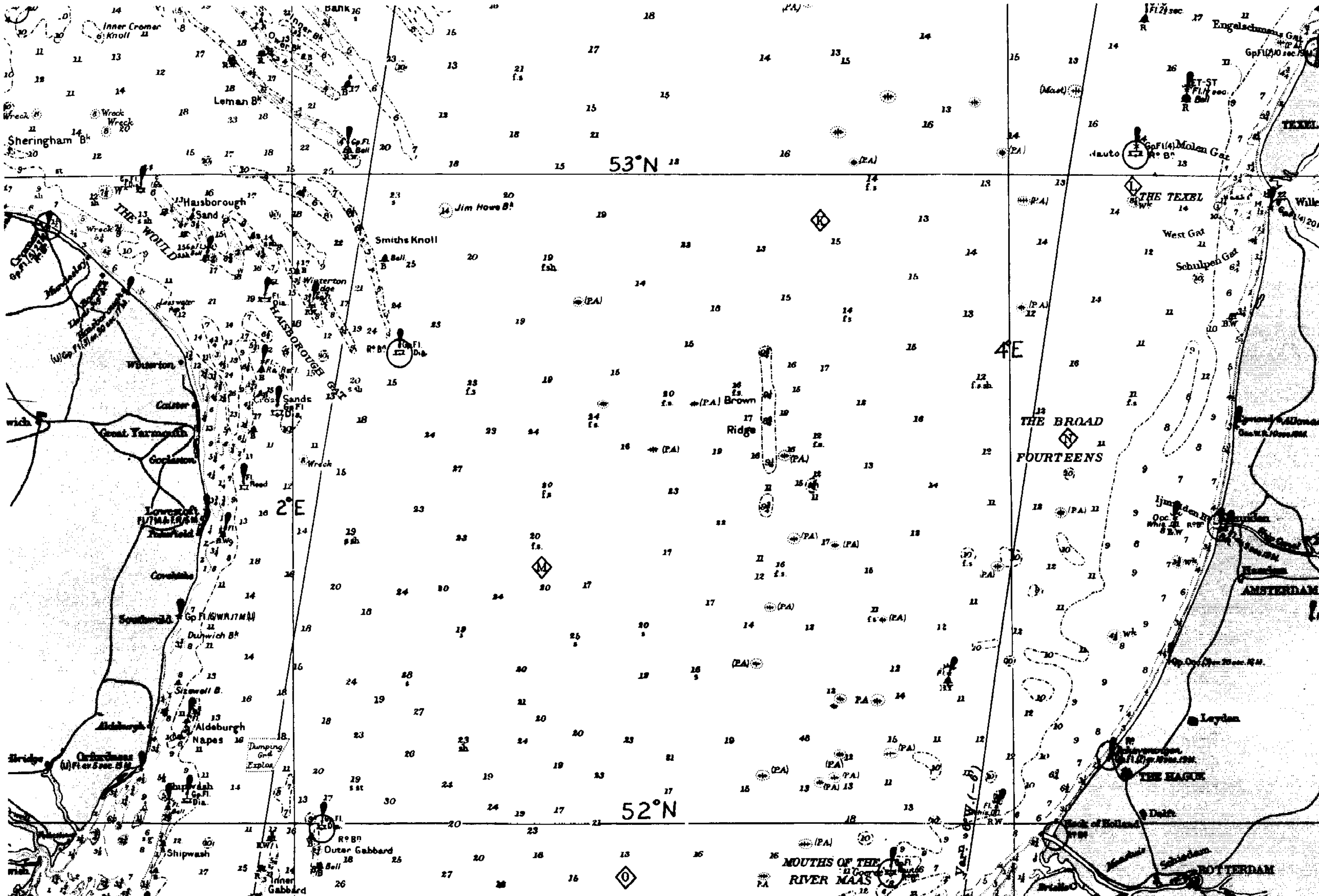
In October 1962 representatives of the Hydrographic Services of Great Britain, The Netherlands, Germany, Denmark, Norway and Sweden met at The Hague to convene the first North Sea Hydrographic Conference. Their aim was to assess the shortcomings of existing charts of the area and of the surveys on which they were based, and to organize international cooperation in the collection of the necessary hydrographic data required now and in the near future. The subsequent exchange of information between the six participating nations proved the situation to be just as bad as had been expected, and left no doubt as to the urgency and magnitude of the task. It was also apparent that reasonable economy in the use of the small surveying resources available would require international agreement on planning and a careful arrangement of priorities. To this end, tracks across the North Sea for ships drawing more than 10 metres (33 feet) have now been selected, so that detailed surveys can at first be concentrated in these lanes.

Already, ships drawing 45 feet are using the North Sea, and Europoort for example, is planning to receive ships of 50-foot draught. The construction and operation of these vast bulk carriers has proved economically sound, so that their size as well as their numbers may yet increase still further. These deep draughts, the high concentration of shipping, the generally poor weather conditions, the shifting sandbanks and the large areas of shallow water at considerable distances offshore, are all factors demanding a high standard of hydrographic information. In addition, the southern North Sea has one of the world's highest concentrations of wreckage on the sea bed.

Surveys of the approaches to the large ports and estuaries are of course already maintained at a high standard, and in general so are the waters within about 15 miles of the shores. But otherwise the North Sea is almost completely unsurveyed by echo sounder or systematic sonar search. In 1937 the Germans used echo sounding to survey a large area between the Humber and Heligoland Approaches, but even this was a very open survey in which lines were run three to five miles apart.

The geology of the southern North Sea, south of a line Humber to Jutland Bank, is such that the existence of unknown rocky outcrops is improbable, and general depths away from sandbank and sandwave areas can be confidently assumed to accord fairly closely with those given in the



53°N
52°N
2°E
4°E
Inner Cromer Knoll
Sheringham Bk
Leman Bk
Haisborough Sand
THE WOULD
Winterton Ridge
HAISBOROUGH GAT
Smiths Knoll
Jim Howe Bk
Winterton
Caister
Great Yarmouth
Gorleston
Lowestoft
Southwold
Dunwich Bk
Sizewell B.
Aldeburgh
Aldeburgh Napes
Orfordness
Shipwash
Outer Gabbard
Inner Gabbard
Brown Ridge
THE BROAD FOURTEENS
MOUTHS OF THE RIVER MAAS
TEXEL
THE TEXEL
Molen Gat
Engelschmans Gat
West Gat
Schulpen Gat
Ijmuiden
AMSTERDAM
Leyden
THE HAGUE
Delft
Hook of Holland
ROTTERDAM

old surveys. This tends to be confirmed by the few modern surveys already completed and also by such work as the merchant ship passage sounding organized by the Norwegian Hydrographic Office. (See *International Hydrographic Review,* Vol. XLI, No. 2, July 1964). From these, it would seem that the sparse soundings provided by the old surveys can be relied upon for routeing the deepest draught ships into waters as shoal as 12 fathoms, though the routes selected would in places be unnecessarily devious until the banks, shoals and sandwave areas have been accurately delineated by modern surveys. But no person in authority can as yet recommend these routes because of the added hazard of uncharted dangerous wrecks, so removal of doubts on this score must be given priority in large areas of the southern North Sea.

An offshore survey carried out by a Royal Naval survey ship in 1961 will serve to illustrate the present poor state of wreck charting. This survey has been chosen as an example because it is the most recent survey available in the southern North Sea of an area which had not before been systematically swept by sonar. There is no reason to suppose that the size and number of wrecks found in it is particularly large — on the contrary, at least a dozen areas of similar size could be chosen in which the number of unknown or badly-charted wrecks would probably be higher. This particular survey covered an area approximately 20 by 40 miles between latitudes 52° and 52°20′ North and longitudes 2° and 3° East. Eighteen wrecks were found in it, whereas records had previously indicated the presence of sixteen. But only three of the wrecks were found within three miles of a recorded position. In fact there was no identifiable relationship between the wrecks found in 1961 and those previously recorded. As to their size, six of them stood more than 30 feet above the sea bed, and the largest was 46 feet high. The depths in this area, about 25 fathoms, are generally as great as any that exist south of the Humber. Consequently, none of these large wrecks is a danger to surface shipping, the shoalest having a depth of 80 feet over it. But transfer a similar situation to an area of a general depth of 14 fathoms, which is in any case more typical in the southern North Sea, and the seriousness of the situation is apparent. Figure 1 reproduces a portion of Admiralty Chart 2182A and there, in an area of similar size to the one considered above and immediately east of it, 13 dangerous (P.A.) wrecks are charted in depths of the order of 13 fathoms. These shoal offshore areas have never been systematically searched for wrecks.

METHODS OF SEARCH

It is generally accepted that the only certain method of determining the least depth over steep-sided obstructions, or of disproving the existence of small obstructions in a given area, is wire-drift or drag-sweeping. For certain tasks of this sort divers are also often used (see below). But in the case of the southern North Sea, about 6 000 square miles require close examination even if the width of deep-draught shipping lanes is at first limited to ten miles, and the forces which would be required to wire-sweep an area of this size are not available.

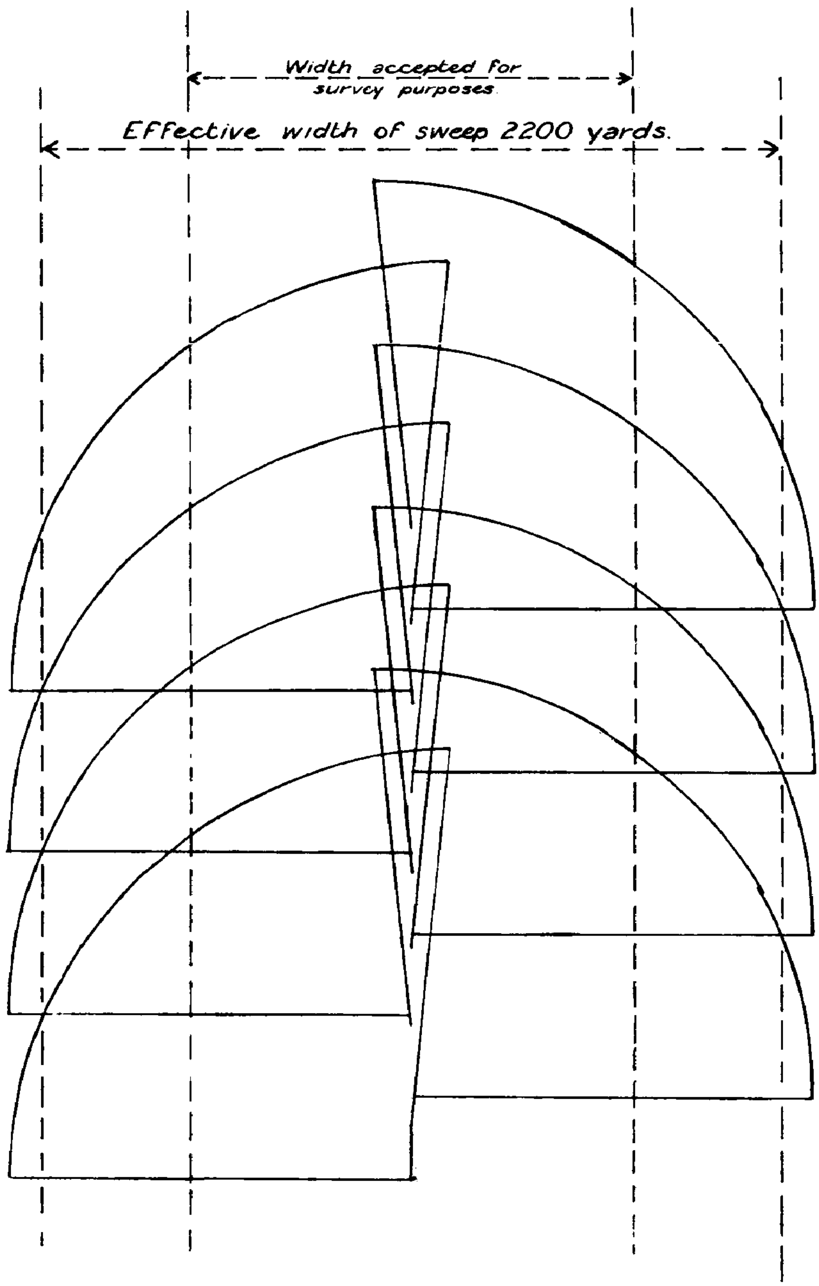


FIG. 2a. — Diagrams of areas swept with :

Range transmission interval ...	2 500 yards
Maximum probable range	1 200 yards
Speed of advance	6 knots

The following alternatives place greater reliance on sonar equipment. They are divided into three degrees of thoroughness, with the object of making the task realistic in relation to the surveying units available.

(i) *In depths of over 15 fathoms*

In these depths the largest ships will have at least 40 feet between their keels and the sea bed. The minimum requirement, therefore, is to guarantee the location of all obstructions with a height of about thirty feet or more. Even though sonar conditions in these turbid waters are generally not good, this requirement can certainly be met by modern sonar equipment.

The first need is to cover the entire area under survey with an effective sonar sweep, plotting the positions of all contacts obtained, but making no attempt to hold the contacts for classification. Once the existence of a sonar contact has been established, classification during the initial search is of less importance than the maintenance of a regular progression of the sweep, so that the actual search resembles the planned pattern as closely as possible.

Search pattern diagrams, depending on such factors as speed of advance over the ground, arc of sweep, bearing interval, transmission time interval and effective range, are easily drawn out, and since small changes in any of these factors can considerably change the characteristics of the sweep, these diagrams should be studied. Figures 2(a) and (b) for example differ only in the speed of advance. The area surveyed in a given time at 10 knots is shown to be a little over 40 % more than that at 6 knots, but at the slower speed every part of the area is swept at least twice whereas at 10 knots nearly half the area is covered only once.

All the factors affecting a sweep pattern can be determined or controlled within narrow limits, with the exception of effective range. It may therefore be of value to consider the meaning of this term as applied to a sonar survey search, particularly as it involves a number of variables and estimations, and cannot be precisely defined.

Suppose, for example, it is decided that all wrecks with a height of more than 10 feet must be detected. The effective range at which such a target will probably be detected must be determined each day. Two observations can assist in this determination — a measurement of the reverberation range at the time and in the area of search, and a graph of the depth/temperature pattern. " Effective range " must then be estimated in relation to the previously determined capabilities of the sonar set under similar conditions. The estimation therefore remains largely a matter of judgement, but it is not good enough to assume a fixed maximum range for a given type of target without regard for the water conditions. Even in the shallow waters of the southern North Sea, sharp thermoclines can occur during the summer months; the surveyor must therefore have a working knowledge of the effects of these thermoclines on the sonar beam.

Assuming that the figure arrived at is 1 500 yards, with a typical 10-knot sweep pattern, this will give a swept path about 2 500 yards wide without gaps — that is 1 250 yards either side of the ship. Theoretically,

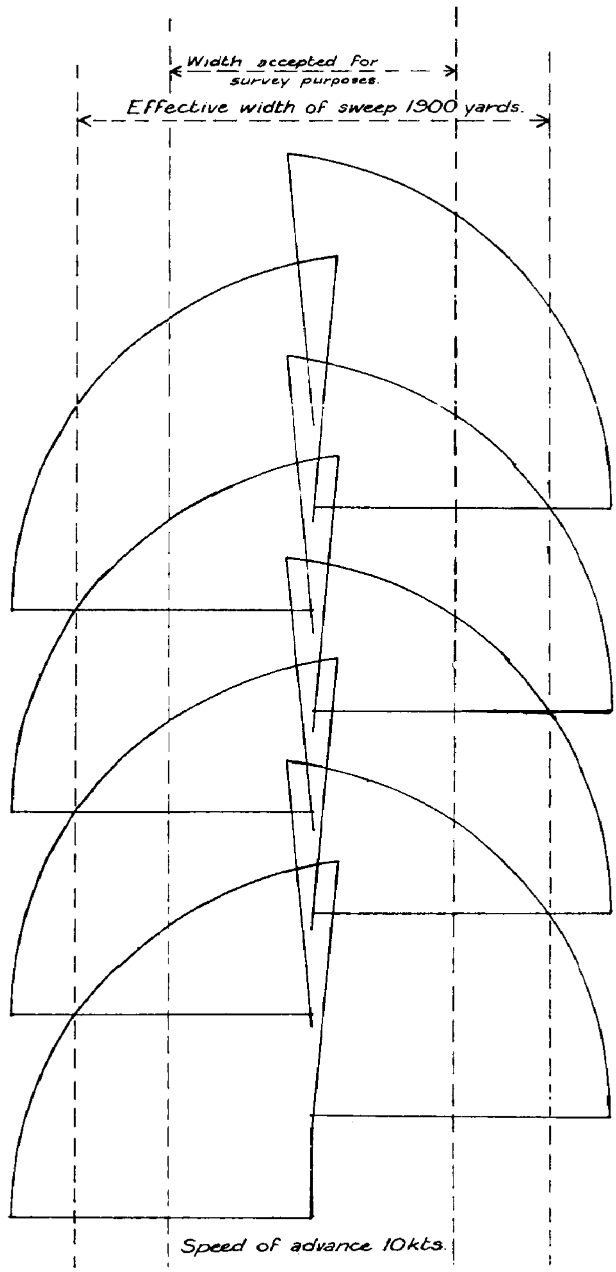


FIG. 2b

therefore, adjacent lines not more than 2 500 yards apart will give at least " once swept " coverage for the entire area, but for survey purposes this distance apart of lines should be reduced by 40 %. This large safety factor is necessary to ensure thorough sweep coverage despite distortions of the planned pattern by less than perfect operation, and by pauses in bearing progression for confirming the existence of suspected echoes.

For waters deeper than 15 fathoms it is considered that two complete and separate sweeps, planned on a maximum probable detection range for wrecks more than 15 feet high, will dispense with the necessity for a search by wire sweeping.

Provided frequencies and siting of echo-sounding and sonar transducers have been chosen to minimize mutual interference, sounding can usually be carried out concurrently with a sonar sweep. But to do this satisfactorily extra personnel must be available to attend to the sounding. On no account should the attention of the sonar team be divided. To facilitate this dual task the second search pattern lines can be run between the first ones and parallel to them. There is no particular advantage from the search point of view in running the second lines at right angles to the first, since contacts are as likely to be made on the beam as they are ahead. This of course does not apply when searching for a wreck, the position of which is fairly accurately known; then the position must be attacked from different directions so that at some stage the wreck presents a good aspect to the sonar beam.

Having thus found and plotted all the sonar contacts in the area, each one in turn is then " attacked ", run over to obtain a vertical echo-sounder trace, and classified. Echoes classified as banks can be ignored at this stage; they will have been (or will later be) surveyed in the course of the sounding. The sonar attacks and the E/S traces may indicate that many of the wrecks are small ones, in which case a few extra E/S runs may satisfy the surveyor that, having regard to the depth of water, they are not worth further attention. These extra E/S runs should be carried out at the time of the first attack so as to avoid the necessity for returning to the spot. It will usually pay too, to obtain three or four E/S traces of the larger wrecks to give some idea of the least depth to be expected; this will save time later when drift sweeping. On the basis of this information the larger wrecks should be divided into two groups — those which will almost certainly be cleared by a towed wire sweep set to 12 fathoms below datum, and those which are probably shoaler and will therefore have to be drift swept to determine the precise least depth over them. The figure of 12 fathoms is specified because dangerous wrecks are now internationally agreed to be those carrying a depth of 20 metres (11 fathoms) or less, and the set depth of towed wire sweeps, even after careful calibration of gear, cannot be guaranteed within closer limits than $\pm$ 6 feet. Thus a wreck cleared by a towed sweep set to 12 fathoms below datum should not be charted at more than 11 fathoms. This is probably a fair generalization for all types of wire sweep towed at speeds in excess of about 1 ½ knots, including those types of sweep in which depth control is maintained by a combination of floats and planing surfaces.

This sweeping completes the wreck survey of the area, except for the disproving of previously charted dangerous wrecks — a subject which will be considered later.

(ii) *In depths of between 11 and 15 fathoms*

Again assuming maximum draughts of 50 feet, these depths give between 16 and 40 feet under the keel. The same principles apply here as for the deeper water, but the sweep width must now be based on the certain detection of smaller wrecks (say 10 feet in height), and the density of search must be increased accordingly.

It is suggested that in these depths the standard sonar should be duplicated by a fixed beam sonar search.

Fixed beam sets are now commercially available. Working on a frequency of about 45 kc/s (which is higher than the standard sonar), they have a range of the order of half a mile, and the direction of the signal is fixed on the beam. In plan the beam is narrow (about 1 ½° as opposed to about 10° for the standard sonar), but in elevation it is wide and covers the sea bed from almost vertically beneath the ship out to the limit of its range. As the ship moves ahead on a steady course successive transmissions sweep out a path about a 1 000 yards wide to one side of the ship. These signals are shown on a straight-line recorder. The recorder paper is mounted on horizontal rollers which revolve at a constant rate, whilst a stylus moves across the paper recording range and echo strength. The picture built up in this way depends on two effects for its interpretation. An obstruction which stands up from the sea bed will not only give a stronger-than-average signal response from its near side, but it will also shield some of the sea bed on the side remote from the ship. The signals recorded are therefore a strongly-marked echo followed by a length of unmarked paper. The length of this " shadow " at a given range and depth varies with the height of the obstruction, so that the recorder gives a representation of the shape of the obstruction. (For photographs and descriptions of two types of this equipment see *International Hydrographic Review*, Vol. XL, No. 2, page 53 and Vol. XL, No. 1, page 49).

Transducers for this equipment can be fitted either internally or externally to a ship's hull; the external fitting may be stabilized against roll. Alternatively, the transducers can be towed astern of the ship below the surface so that they are clear of aeration effects and the disturbance of wave action. In the latter case the transducer is housed in a streamlined free-flooding container. In a large ship the hull fitting will usually be the more convenient if it is to be used for wreck examination, with its attendant sharp alterations of course and speed, or if it is to be used in conjunction with towed wire sweeping to provide a useful check that the sweep has passed over the entire wreck. In smaller ships the towed fitting, with its advantages of cost, ease of installation and ease of transfer if necessary from one ship to another, will usually be preferable.

Whichever type is used, the permanent record of signal response over the whole of the area under survey which the fixed beam set can provide is an important addition to the total information. When undertaking a wreck survey of this type in these depths a permanent sonar record, which can be analysed and checked at leisure, should be given as much attention as the echo sounder trace.

Also the higher frequency and narrow beam width of this equipment give better discrimination and increase the chances of detecting the smallest obstructions.

In deeper waters, even moderately attentive operators could hardly miss the loud pings on the ahead-training sonar returned from a wreck of any importance. But in shoal waters, where small wrecks can be dangerous, there must be some safeguard against the possibility of the bridge personnel's attention being distracted at a vital moment. The record of the fixed beam sonar provides this, but in any case the ahead-training set should always be fitted with a bridge loudspeaker.

The same " safety factor " of 40 % should be applied whichever type of sonar is employed.

In waters of between 11 and 15 fathoms, in addition to the double sweep suggested for the deeper water, at least one complete sweep by fixed beam sonar is recommended. If a second beam sweep is considered necessary, the lines in this case should be run at right angles to the first.

Provided their frequencies are deliberately selected to avoid mutual interference, it should be possible to operate ahead sonar, beam sonar, and the echo sounder all at the same time. With careful organization of bridge personnel, this should be practicable in the major survey ships; in coastal survey craft, concurrent operation of any two of the three would probably be all that could be successfully achieved — both because of the numbers of watchkeeping personnel available, and the layout of bridge receivers.

(iii) *Depths of less than 11 fathoms*

Throughout the southern North Sea deep draught ships can be conveniently routed clear of lesser depths than 11 fathoms until entering river estuaries or port approaches. Even so, long distances of shoal water are involved; for example more than ten miles seaward of Europoort (Hook of Holland) and more than thirty-five miles seaward of Thames Haven. To wire sweep routes along the entire length of these approaches would be an expensive undertaking employing survey ships and crews for long periods; it may prove to be too prolonged a task for the resources available, but certainly it must be considered. Where the sea bed is flat or only gently undulating, it should be possible to rely entirely on sonar searches for detecting small obstructions even within the 11 fathom line in some places, but it would be pointless to speculate on precise divisions between areas to be wire or sonar swept, without thorough evaluation of results using up-to-date equipment in a few sample areas.

A further factor which requires study is a determination of a precise figure for the least depth in which a 50-foot draught ship can safety operate under various conditions. The British National Physical Laboratory (Ship Division) has made a study of some aspects of this problem for the Southampton Harbour Board. The results have not been published, but in a general reference to them, a Southampton Harbour Board spokesman has stated (*) that, due to shallow water effects, a maximum increase in draught of 4 feet 6 inches at speeds in excess of 12 knots had been found, and an increase of over 2 feet at 10 knots. A list or roll of 1° increases the draught of these ships by 1 foot. Finally, allowance must be made where necessary for lack of accurate tidal height information.

(*) The Dock and Harbour Authority (November 1963).

Dredging the main Needles & the main channel of Southampton Water.

Drift sweeping

The techniques of drift sweeping are fully described in various surveying manuals, and all North Sea surveying units have certainly had plenty of opportunity to practise them since 1945. Usually, the results are determined to the same degree of accuracy as the sounding — according to United Kingdom practice in open water — to the nearest foot. A " bracket " of a clear and foul sweep separated in depth by not more than one foot is required. In open waters in the North Sea where as often as not conditions are too choppy for wire drift sweeping between a pair of boats, but are quite satisfactory for ship drift sweeping, this work is notoriously a time-consuming activity. For the first stages of this North Sea wreck survey it is suggested that a determination of least depth within a bracket of 3 feet will be sufficient. This will lead to a maximum charting error of 2 feet on the shoal side.

With a ship's length of say 230 feet, two or three drifts overlapping each other are often required to guarantee that a wreck is clear at the set depth. As fouling may occur during the last sweep at that depth, a 3-foot bracket will frequently require four or five less sweeps than a 1-foot bracket. In practice, acceptance of this approximation has been found to increase a ship's " output " of wrecks swept by at least 30 % during a major wreck survey. The completion of two wrecks on one tide would not have been possible in many cases without it.

Resurvey and wreck movement

The Hydrographer of the Navy has always accepted the possibility that strong tidal action can cause rolling, up-ending or breaking up of a wreck in such a way that the least depth over it is decreased. As a result instructions are laid down for the resurvey of wrecks at set intervals. Buoyed wrecks for example should be resurveyed every three years, and dangerous wrecks in main shipping channels every ten years. In practice it has not been possible to implement these instructions in full, but at least the need is recognized.

An examination of British Hydrographic Department records was made during 1963 for wrecks which had been found to have a less depth over them on resurvey. The worst cases, up to 10 feet less, were found to be post dispersal operation sweeps, and the lesser depths here were assumed to be due to plates or spars bent or up-ended by the explosions. Amongst the remainder, four feet was the greatest decrease which could be found. As this amount could be accounted for by factors other than wreck movement, the evidence was inconclusive. A combination of small wreck movements and errors in swept depth and tidal reduction might possibly have been the cause.

But in June 1963 the German Hydrographic Institute circulated a report which goes a long way towards proving that dangerous movement of wrecks can take place. The report concerns a study of six wrecks off

Borkum which have shown a decreased depth on resurvey, and on which dispersal explosives have not been used. All these wrecks had been inspected in detail by divers at intervals of between nine and fifteen years, and from the divers' reports sketches had been drawn of the attitude and state of the wrecks and their surrounding scours. These reports included horizontal and vertical measurements along the length of the wreck.

Amongst the effects indicated by these reports are :

(i) In 1951 a partly disintegrated wreck lay on an even keel. Nine years later the bows had fallen into a deep scour so that frames at the stern had been lifted. Result — 4 feet less clear water.

(ii) In 1951 a wreck on its beam ends was embedded in sand with a deep scour around the length of the keel. Ten years later, the scour had disappeared and the wreck was upright. Result — 9 feet less water.

(iii) In 1951 a wreck was embedded in unscoured sand. Nine years later deep scours had formed at bow and stern and the ship's back had been broken on the ridge amidships. Result — raising of the midships upperworks and 5 feet less water. In 1956 the scour around this same wreck was amidships and the stern was then the highest part; there being 7 feet less water as compared with 1951.

These findings will have practical consequences, and more observations are needed.

In the centre of the southern North Sea (around 52°20′ North, 3° East) a large area of sandwave formations exists. These waves reach a height of at least 50 feet from trough to crest and massive transport of sea bed material is known to take place in them. No observations on wreck movement have been made in this area and indeed, little is known at present about the movement of the sand waves themselves. But it is a reasonable assumption that rapid and heavy scouring forms around these wrecks, and it might be expected that this in turn leads to a lowering of the centre of gravity of the wreck even though least depth may be decreased by a change in attitude. But can a wreck at one time completely covered by sand reappear between sandwaves at a later date and if so, can this happen to an extent dangerous to surface ships, and what sort of time scale is involved ? Only detailed surveys of selected wrecks in the area could answer this with certainty.

Wreck movement is undoubtedly important, and the resurvey of wrecks in some instances is necessary because of it. But the most urgent wreck task in the southern North Sea is the primary search to locate and survey all dangerous wrecks and, where appropriate, to disprove the existence of such wrecks in their present charted positions.

Removal of dangerous wreck symbols from charts

The North Sea Hydrographic Committee, whilst acknowledging the undesirability and possible legal complications of attempting to define exact limits of areas of North Sea surveying responsibility, nonetheless hope that by advance planning, they can promote the economical use of the total resources available amongst the countries concerned; and this will inevitably mean the allocation of certain offshore areas to the hydrographic organizations of individual ocuntries. The offshore waters in an area south of 53° N and east of 3° E, for example, will probably be surveyed by the Netherlands. In this area alone, about 20 dangerous wreck (P.A.) symbols are charted. About two-thirds of these have been inserted on British Admiralty charts on the authority of the Netherlands, whilst the other third have been inserted on their charts from the British.

It is axiomatic in this country, and also no doubt in the other five countries involved, that a wreck once charted as dangerous remains so until proved otherwise. But there would be advantage in ensuring that all countries apply comparable standards to the minimum search acceptable as " proof ", before authorizing the removal of a dangerous wreck symbol.

An examination of records of the (P.A.) wrecks in this particular area gives very little information on the accuracy of the reported positions of some of them. But positions rounded off to 5 minutes of latitude and longitude (and in one case to 10 minutes) without further details, instil no confidence. It is thought quite possible that a few of the wrecks could easily be charted as much as ten miles in error.

To apply the most rigorous searches to an area within 10 miles of each (P.A.) wreck is obviously impractical. Apart from the work involved, experience shows that in these areas it becomes impossible to relate wrecks found on surveys to the positions of previously reported wrecks. In any case, it is arguable that even on the scale of a general chart of the southern North Sea, a wreck symbol shown more than five miles away from its correct position is of no value whatsoever. On larger scale charts, where good navigational aids are available, this figure of five miles can probably be reduced.

Many of these (P.A.) wrecks are old ones — First World War or before — so it will be surprising if some of them have not entirely disappeared. For proof of this disappearance, it is suggested that the area should, in the first place, be searched to the standards for general search outlined above according to the depth of water. Then, provided this first search has covered the area to the limits within which the charted (P.A.) symbol has any value (say a maximum of 5 miles, whatever the scale of chart), a further search within two miles of the charted position should be acceptable as proof of disappearance.

The methods outlined for the general searches already provide fairly rigorous cover, and necessarily so in view of the heavy concentration of wreckage in the area and the poor standard of existing charting and records, but this does at least mean that within this coverage the job of disproving previously reported wrecks is already half done. In fact, a repetition of the general search required by the depth of water, with all lines run at right angles to those of the first search, should provide sufficient proof; the second search covering an area within two miles of the reported position of the wreck.

When considering an isolated offshore dangerous (P.A.) wreck, not within an area covered by a general search, it would be unrealistic to assume that a thorough search within two miles of the reported position could disprove its existence. There would seem to be no alternative in these cases to extending the search to at least 5 miles.

The Use of Divers

Diving as an aid to surveying is now widely practised both in government organizations and commercial surveying units (see *International Hydrographic Review*, Vol. XL, No. 1, January 1963), and there is no doubt that divers can often save a survey unit a great deal of time in determining such factors as the highest point of an obstruction, in addition to providing information which could not have been found in any other way. Conditions in which a survey diver may operate, however, vary a great deal. In one case he might be working in comparative comfort in clear, tideless waters in which he has a range of visibility of well over 100 feet, whereas in another his work might be restricted to half hour periods at slack water and in complete darkness in depths of as little as 30 feet. Under these circumstances the diver may not only miss the high point of the obstruction entirely, but finds it difficult to retain a reasonably accurate sense of the horizontal plane. Only under favourable conditions, therefore, would it seem reasonable to accept the uncorroborated work of a diver as the basis for charting the least depth over an obstruction. However, even in poor conditions, a diver's work may save time in examination, but in these cases the results of his work should always be checked by a final wire clearance sweep.

Developments in equipment

There would be considerable benefit to surveyors in the development of a fixed beam towed sonar set which can transmit and search an area to port and starboard simultaneously. So far as is known such an instrument does not present any great technical difficulties, but it would of course involve the fitting of twin amplifiers and recorders as well as transmitters. But the characteristics of sound waves of about 40 to 50 kc/s in water, which are the frequencies best suited to this equipment, are such that ranges of much more than half a mile cannot easily be obtained. Greater swept width is thus only possible with the double sweep. To make full use of such an instrument, the transmissions on each side would have to be so arranged that they and the echo sounder between them, search a continuous strip from one side, under the ship, out to the limit of range on the other side.

Sector scanning is now being widely developed, and this too may have surveying applications. Here, the transmitted beam is about 30° wide but the receiving oscillator is able to discriminate quite finely, within about 1 ½°, between the bearings of returning echoes within the 30° sector. One transmission can thus provide ranges and bearings of echoes within this wide arc, which in turn means that a sector of 180° can be searched in about a tenth of the time required by a conventional training sonar set.

This sector scanning is achieved without physical training of the receiver. Instead, the receiver consists of dozens of small units set in a row which are scanned or balanced electrically. For bearing discrimination it makes use of the fact that a sound wave received from a direction other than at right angles to the oscillator face will arrive at one end of the row later than the other, and this delay is electrically measurable.

Control of Position

Fixing accuracy is a requirement common to all facets of North Sea offshore surveying work, but wire sweeping needs a high standard of repeatability of positioning if overlaps are not to be uneconomically large. Repeatability in this sense is taken to mean the limits of error within which a plot or instrument can be relied upon to give the same answer on each return to a certain position over a given period of time. Thus, to say that the repeatability of a decometer is within ± .015 lanes during summer daylight, gives no indication of the absolute error of the reading, but only that the spread of readings taken at one position over a period of time will not exceed ± .015 lanes. When using a drift sweep 200 feet long for instance, overlaps of as little as 50 feet are accepted; the ship's position on the plot must then be less than ± 25 feet in error compared with its immediate surroundings if gaps in the swept area are to be avoided.

Apart from the usual methods entailing the mooring of reference markers in the close vicinity of the wreck, absolute accuracies of this order can be achieved out of sight of land by well-sited survey Decca chains, or by radar if positive and coordinated targets are within range. The repeatability of navigational Decca chains may be good enough in some areas in good propagation conditions to warrant their use for fixing sweeps with overlaps as small as the 50 foot quoted, but every precaution must be taken to guard against undetected short-term fluctuations in variable errors. These precautions include :

(i) Mooring a small reference buoy (a pellet may be enough), and checking Decca readings against it at frequent intervals; during a drift sweep this can be done each time the ship is manœuvred into its up-tide position for the next sweep.

(ii) Frequent referencing of the decometers.

(iii) Consideration of the diamond of error of the fix produced by the limits of sensitivity of the instrument to its received signal.

(iv) Plotting of the Decca fix as frequently as practicable during the sweep and smoothing out the more obvious anomalies; this is justified since .01 lanes will be easily plottable on the scales normally used for expanded sweeping plots.

Navigational Decca chain signals frequently involve considerable land paths; then, because of changes in ground conductivity and propagation conditions, it may happen that a Decca fix taken over one end of a wreck gives a displacement of several hundred feet as compared with a similar fix observed a few weeks earlier. This in itself does not invalidate the use of the chain for sweeping since propagation conditions may be quite stable during the time required for the sweep; but the above checks will be necessary to ensure that this is in fact the case.

Conclusions

Until a few years ago, the only sonar equipments available for surveying purposes had been designed for anti-submarine work. For this purpose they were fitted with a number of refinements which did not make them any better as wreck-searching tools, but considerably increased the maintenance effort required to keep them in good order. A sonar designed specifically for surveying purposes would have a more powerful transmitter and amplifier and a slightly lower frequency than is generally available in the commercial equipment sold for fish finding, but otherwise, apart from alternative hand or automatic training, gyro stabilization for bearing, and loudspeaker extensions, the equipment needs to be kept as simple as possible.

The continued development of the fixed beam sonar set must be a matter of great importance for surveying, largely because it can provide a permanent record of the sweep of an area, in much the same manner as the echo-sounder trace provides the record of a line. The interpretation of a beam sonar trace is admittedly not quite so straightforward as that of an echo-sounder trace, and further studies of these are required.

It is unlikely that developments of beam sonar will oust wire sweeping for the determination of least depths over obstructions, but existing equipment is already capable of providing the evidence to show that wire sweeping is not required over large areas where it would previously have been thought necessary.