This chart is not as accurate as those of Cape Town or False Bay where a base control between Simon's Bay and Gordon's Bay by rocket was the basis for fixing the positions of land features. In addition the distance between Devil's Peak and a Cape peak was determined by astronomical methods as these lie almost on the same meridian and are intervisible.

Similar surveys of a high standard of accuracy were made of the Bays of Conducia, Mokambo and Mombas (Mombassa) during the same voyage. In 1858 Francis Skead and members of the Zambezi Expedition used masthead determinations to survey the Zambezi Delta and River to above Tete. The earlier surveys by three officers of the famous Canoe Expedition in the Lower Zambezi are not known to me.

I think Raper described the method in his books on navigation, but I have not been able to find a copy; the second edition was published in 1842. I have a photostat copy of Becher's work published in 1854 and find it very useful as it gives tabulations for heights of the main truck of 30, 35, 40 and 50 ft., common heights for modern yachts. The distances are given in miles and yards; the tables are actually fuller than this, being in intervals of 5 ft. and then 10 ft., up to 208 ft.

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Collisions and Groundings

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THE number of collisions and groundings and the contact damage suffered by merchant ships every year is considerable, the averages for the years 1965–70 inclusive showing that some 15 per cent of the world's shipping over 500 g.r.t. has been involved annually in such accidents. United Kingdom shipping is no exception, and collisions and groundings alone as reported in *Lloyd's Daily Lists* during the first four months of 1971 show that ships from some 27 companies were involved, some with more than one incident reported although none had more than three. Collisions, groundings and contact damage are likely to occur if a ship's captain and his bridge watch keeping officers do not have immediately available in a simple form, complete information about their ship and her navigational equipment, and detailed information covering the essential tasks performed on the bridge. Unfortunately however, in a great number of ships, most of this information is not provided in an easily usable form and, as a result,

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even the most competent of navigators is all too often unnecessarily placed in a difficult and sometimes dangerous situation.

As navigation consultants we aim to assist shipowners to reduce collisions, groundings and contact damage by providing the necessary information for the navigational task, by installing efficient training aids and by analysing bridge manning requirements (including watchkeeping) to arrive at optimum manning figures.

1. Information. It goes without saying that the Captain and his officers must have a complete knowledge of the capabilities of their own ship if they are to carry out their job safely and expeditiously. They must also have complete details of all navigation equipment on board and the Officer of the Watch must have all information for the essential tasks which he may be called upon to perform. The navigational details of the ship and the record of her performance under all conditions of wind and weather would for example include turning and stopping data, recommended pilotage plans and visibility diagrams.

Turning and Stopping data. Figure 1 shows typical (although mythical) turning

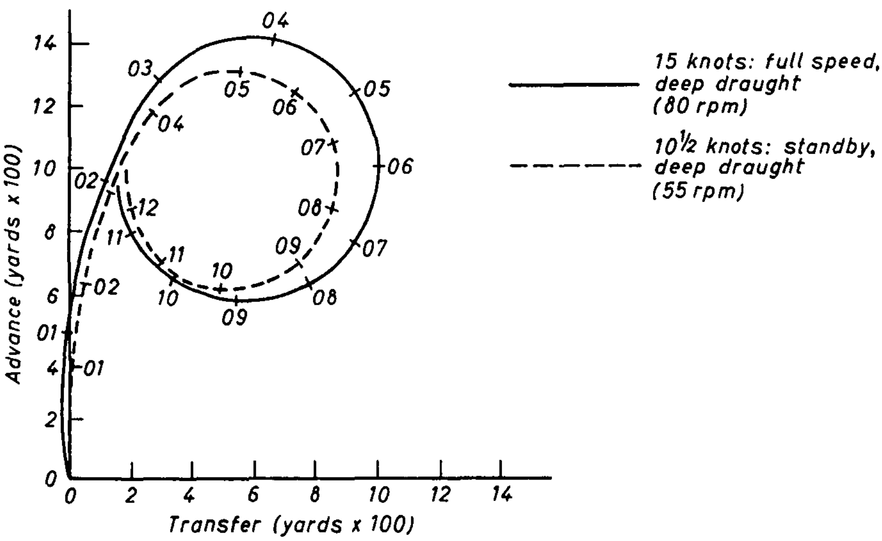

FIG. 1. Turning data—full rudder

characteristics for a very large tanker while Fig. 2 shows her typical stopping distances. The advance for a turn of 90° and the transfer for a turn of 180° (or tactical diameter) are of the order of ½ mile and the time to turn 180° of the order of 6 minutes. On a crash stop she will run for about 2 miles, losing steering control very quickly and generally (with a right-handed screw ship) ending up to starboard of the original track and at an angle to it of the order of 90°. If engines are put to *Stop* only she will run for about 6 miles before coming to rest, although in good weather she will probably be able to maintain steerage way for about 4 miles.

This kind of information which is vital in pilotage so that wheel-over positions may be plotted correctly, in berthing, and in collision avoidance when the time to turn towards or away from another ship and the distance covered must be

Original speed and condition	Change of heading	30°	60°	90°	120°	150°	180°	270°	360°
15 knots deep laden	Time (mins. secs.)	2·35	3·17	3·49	4·24	5·02	6·00	8·52	11·46
	Advance (yds.)	1170	1360	1400	1340	1235	1000	520	1000
	Transfer (yds.)	200	400	600	790	940	1000	595	150
	Speed (kt.)	12·0	11·1	10·0	9·2	8·5	8·0	8·0	8·0
10½ knots (standby) deep laden	Time (mins. secs.)	3·30	4·24	5·08	5·42	6·24	7·45	10·06	12·40
	Advance (yds.)	1100	1280	1320	1300	1180	930	620	1000
	Transfer (yds.)	210	400	585	710	805	880	520	160
	Speed (kt.)	9·5	8·0	7·0	6·6	6·3	6·0	6·0	6·0

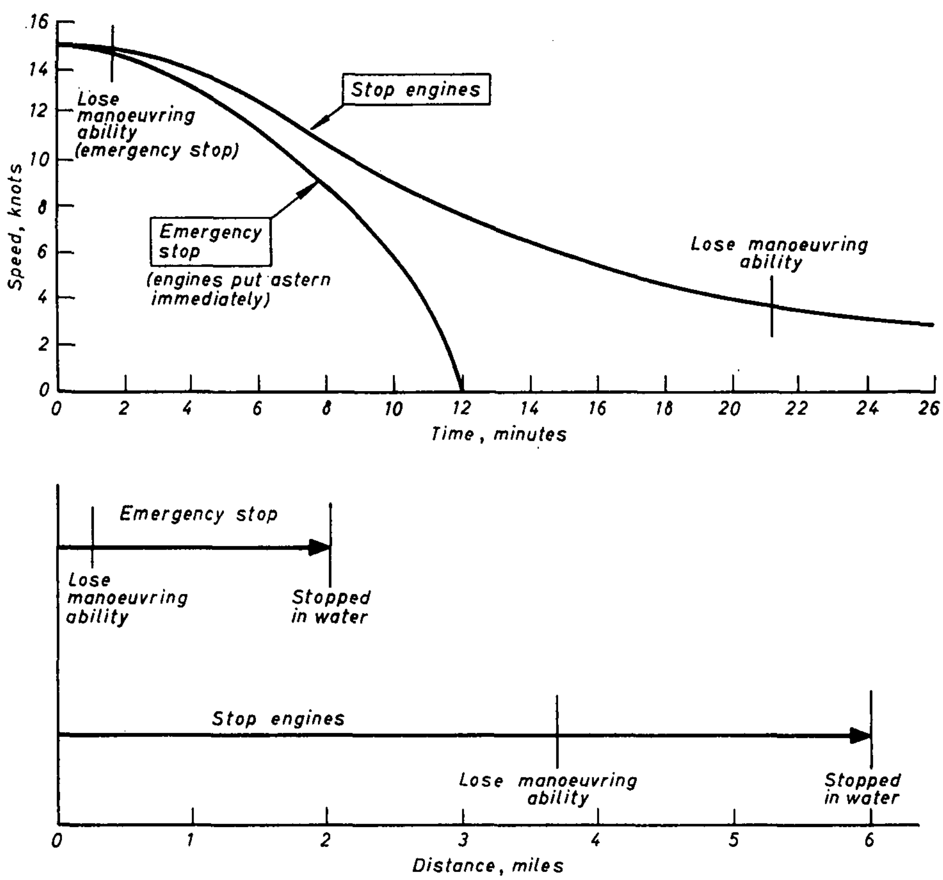

FIG. 2. Stopping characteristics

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accurately known, is frequently not available to the man on the bridge and may not even be available on board.

Recommended pilotage plans. In very confined waters the highest degree of accuracy is required and the exact position of the ship must be known continuously and instantaneously. No delay in establishing this position is acceptable and it must immediately be clear if the ship is being set to port or starboard of track. One should therefore have a predetermined track and know precisely the limits within which one can work, to bring into play *all* the navigational aids available on board, in particular gyro compass, echo sounder and radar.

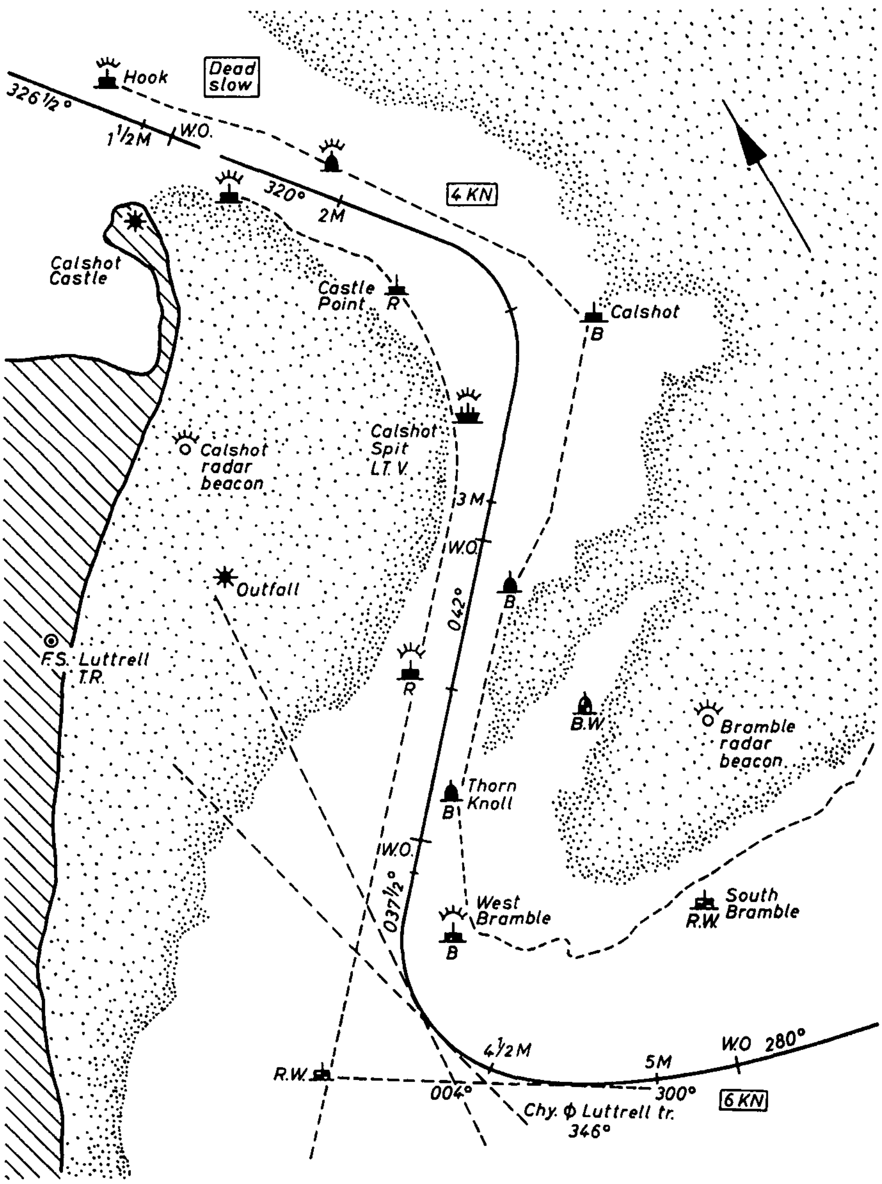

FIG. 3. Recommended pilotage plan for larger tanker entering Fawley

Figure 3 shows part of a chart of Southampton Water prepared for the entry of a very large tanker. The courses are drawn in and marked and wheel-over positions are plotted. Clearing bearings are drawn and noted and the distance to the berth is also marked. All this information is abstracted on to appropriate sheets with which, and the prepared chart, the Master is in a much better position to carry out his task. He can see at a glance the limits within which he can operate and is therefore in a much stronger position to complement the work of the Pilot.

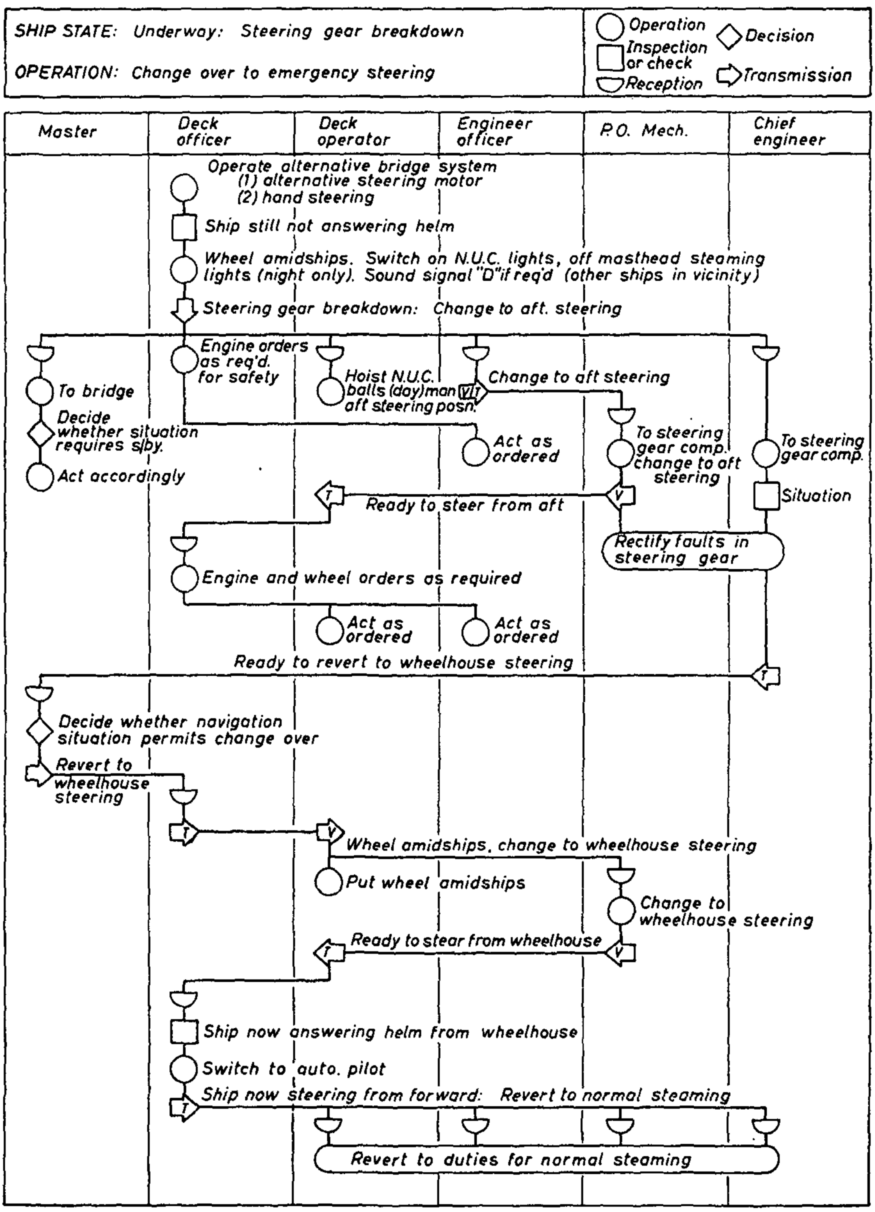

FIG. 4. Operational sequence diagram: steering gear breakdown

Visibility diagrams. In a big ship with the bridge aft a large area forward of that ship is obscured by the hull so that an object in the water could be as much as ½ mile forward of the bridge position and yet not be visible from it. Such information, invaluable particularly in the berthing and pilotage situations, is frequently not available.

The essential information which the Officer of the Watch needs to perform his various tasks can be set out in a Bridge Guide, relating to emergencies, watch procedures, rescue, &c.

Emergencies. An operational sequence diagram (Fig. 4) can, for example, show the action to be taken by the people concerned when there is a steering gear failure, an all too common cause of grounding. By knowing precisely what to do, and in what sequence, and by practising it frequently in safe conditions, this kind of hazard is reduced to a minimum. The action to be taken is displayed pictorially which enables the whole operation to be seen at once and at the same time shows the details, their sequence of operation and their relationship one with the other. Thus a means is placed in the hands of the operating team to ensure the ordered operation, and for the man who is unfamiliar or inexperienced an easily understood representation of the operation and the best means of executing it.

Watch procedures. Diagrams should be available on board to make such tasks as collision avoidance simpler yet more accurate, while at the same time reducing the necessary minimum warning time of another ship's approach. They should be developed in accordance with own ship's turning characteristics, loss of speed while turning and gain of speed when the ship has steadied on her new course. Figure 5 shows a relative motion collision avoidance diagram (REMCAD) for a loaded quarter million ton tanker with similar turning characteristics to those shown in Fig. 1.

It shows the nearest position another vessel can be allowed to close on a collision course, at speeds relative to the tanker of up to 55 knots, before it is necessary for the tanker to alter course to avoid the other ship, allowing a safety margin of 1 mile. The alteration of course would be away from the other ship, except where the other vessel is between right ahead and 112½° on the starboard bow when the alteration would be to starboard, that is towards the other vessel and under her stern. An alteration of this nature would be consistent with the present Regulations for the Prevention of Collision at Sea.

If another ship *B* is 10½ miles away on the port bow as shown in Fig. 5 and if her range is decreasing at the rate of 3½ miles every 6 minutes, the relative speed of of approach is 35 knots. If both ships maintain their present courses and speeds collision will occur in exactly 18 minutes' time. If the approaching ship does not alter course to avoid own ship, *A* must by the rules hold on until the last minute and then take such action as will best aid to avert collision. The diagram shows when this last moment has been reached and it will be seen that this is when the approaching vessel reaches the 35-knot curve, or 4 miles away. If ship *A* now alters course to starboard she should pass about 1 mile clear, the safety margin referred to earlier. Without this kind of information the man in charge of the bridge may well leave the alteration until a great deal later, perhaps until 1½ miles or even closer, and this will almost certainly be too late.

This diagram can be developed for use as an overlay on the radar display or in conjunction with the automatic relative plot, or it can be used as a collision avoidance calculator on its own.

Using the calculator the alteration of course required to pass a specific dis-

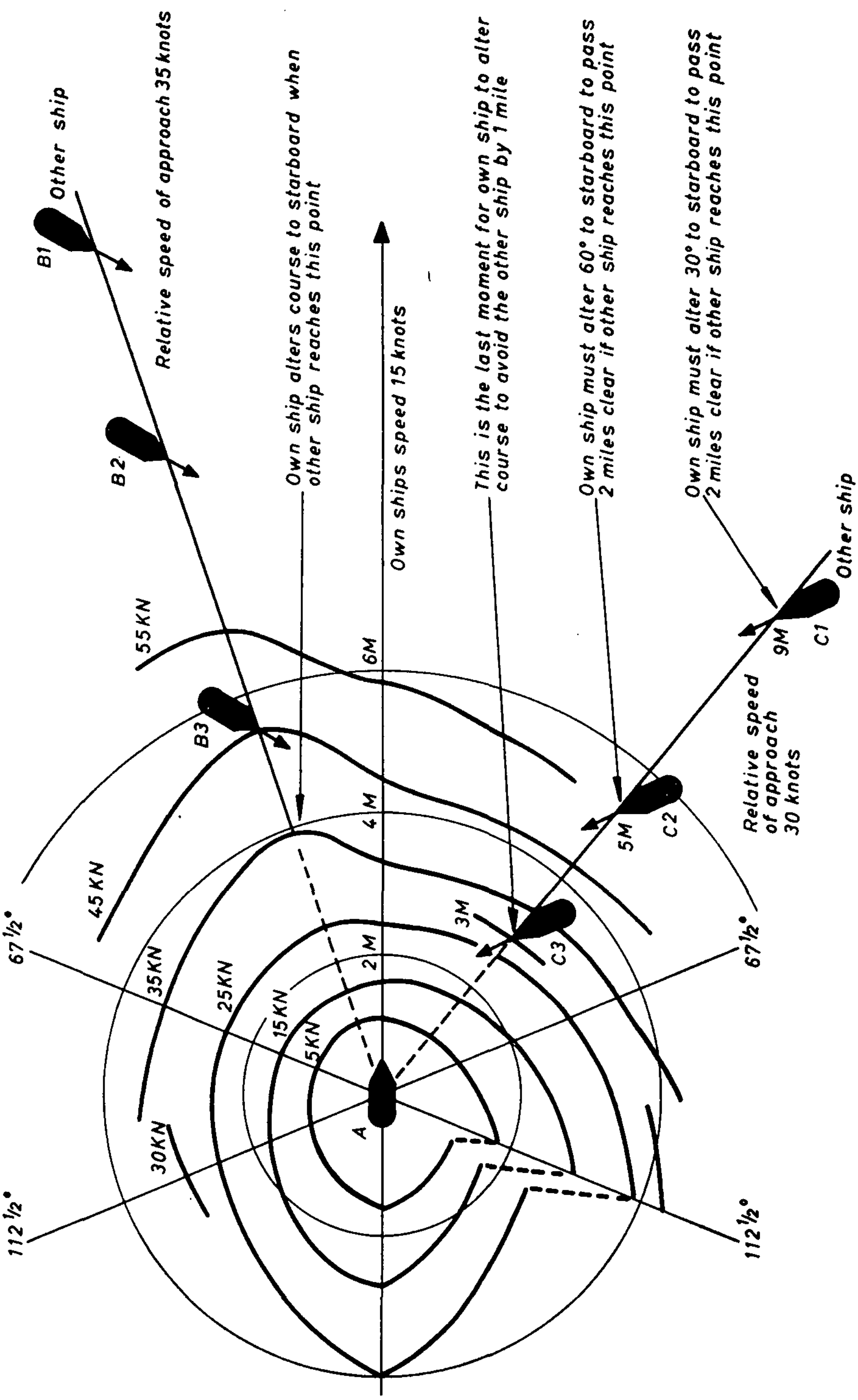

FIG. 5. Relative motion collision avoidance diagram

tance clear of another vessel can be quickly determined. Examples are shown in Fig. 5 giving the required alteration of course to pass 2 miles clear of another ship approaching on the starboard bow, given the particular circumstances ($C1$, $C2$). For a variety of reasons it may be necessary to hold on until the last moment before altering course to starboard and giving way to the other vessel by going under her stern. The REMCAD curves show when this last position has been reached, in this particular example the distance would be 3 miles, once again allowing the safety margin of 1 mile.

For normal service and 'stand-by' speeds one set of curves per ship would probably be sufficient, as the ship's turning characteristics at these two speeds would probably be very similar. Of course, as a ship reduces speed the relative speed of approach of any other vessel alters, so giving an up-dated 'last-moment' for wheel over. For speeds below 'stand-by' it would depend very much on the turning characteristics whether a further set of collision avoidance curves would need to be prepared. However, as advance and transfer would be reduced while time to turn would be increased, there would be a tendency for these factors to cancel each other out.

Operating procedures. Information on operating procedures, including the maintenance and checking of navigational equipment, should provide all details of navigational equipment, compasses, radars, radio fixing and plotting aids, &c., including their capabilities, limitations and likely errors. This should be presented in an easily understandable form, for example the operational sequence diagram already mentioned. A work information card for checking the accuracy of the echo sounder to ensure that it records the correct depth of water below the transducers would, for example, give sufficient information for the equipment to be correctly identified as well as the level of skill, tools and conditions needed to carry out the task, and the procedure. Where appropriate it would show the safety precautions to be observed. It is absolutely vital that any error in navigational equipment is quickly recognized and either allowed for or eliminated. This will be achieved by organizing the operating, maintenance and checking procedures along these lines.

2. TRAINING. Once the essential information has been provided, efficient training aids should be instituted to develop levels of skill. These training aids should include:

(i) Synthetic (that is pre-set) collision avoidance plotting exercises, on a simple to complex scale.
(ii) Training in the use and maintenance of navigational equipment.
(iii) Chartwork exercises.
(iv) Training programmes for navigating cadets.
(v) Training programmes for senior deck ratings.
(vi) Training of deck operators not only in steering and look-out procedures but also in simple plotting and navigational operating and maintenance tasks. This makes the job a great deal more interesting and will produce a much better response from the individual.

The emphasis must be on sea training, that is training on the job, an invaluable complement to the more formalized methods of shore training to ensure that the lessons learned ashore are put into practice at sea and not forgotten.

The great virtue of training aids of this kind is that those on board can practise beforehand the kind of situation which they are likely to meet, for example in the congested waters of the English Channel in bad visibility. A large tanker on a run from the Persian Gulf to the United Kingdom, with perhaps up to 20 days in clear weather with little traffic, can derive tremendous benefit from aids such as these. Not only is the expertise of the bridge watchkeeping officers and men increased, but when the ship does reach the Channel they are on their toes, mentally keyed to deal with any situation. Boredom and lack of enthusiasm, common features of present-day long sea passages, are eliminated.

3. BRIDGE MANNING AND LAYOUT. The scale of manning must take into account the four principal navigational situations:

(1) Open waters;
(2) Coastal waters;
(3) Pilotage waters;
(4) Berthing, unberthing, anchoring and weighing.

Each of these would in turn be modified by day or night conditions and good or bad visibility, giving in all a total of 16 possible situations, for each of which the manning requirement (including watchkeeping) should be analysed in the light of the type of equipment fitted and its layout on the bridge. By critically examining the bridge task an optimum manning figure can thus be arrived at, while the task of planning future developments in navigational equipment and bridge layout will be simplified.

4. CONCLUSION. Information and sea training bring about an improved level of competence which, together with safe operating procedures, will reduce groundings, collisions and contact damage and in this way increase safety, save lives and reduce pollution. The benefits are considerable for, given an operating life of 20 years, a ship runs the risk of being involved three times during that life in a grounding, collision or contact damage incident. The current average direct cost of repair or replacement would appear to be of the order of £40,000 per incident, a total of £120,000 in a ship's life, and much more than that for really large vessels costing perhaps 10 or 20 million pounds. When tankers are concerned there are the pollution costs as well; the *Torrey Canyon* settlement of £3 m. may well have been less than the total expenses involved. It is not unreasonable to suppose, therefore, that three accidents in the life of a really large vessel could well cost something of the order of a million pounds and perhaps a great deal more.

If the provision of aids along the lines put forward in this paper were to cut the accident rate by only 25 per cent, the benefit per ship could be of the order of £30,000, and even a quarter of a million or more for very large vessels, while a reduction in accident rates would be bound to have a stabilizing effect on insurance premiums.

Lateral Error on Airways

J. D. Proctor

A. WHITE's study of navigational accuracy near Strumble [1] is artificial and draws some wrong conclusions. He seems to assume that it is a crime to be outside the airway. But this airway is isolated, with no mountains near cruising altitude, and