TABLE 1

| $i$ | $\theta_i$ | $\phi_i$ | Course | Distance |
|---|---|---|---|---|
| 1 | 5° | 4° 58·9′ | 045·22° | 423·20 |
| 2 | 10° | 9° 51·1′ | 045·86° | 840·12 |
| 3 | 15° | 14° 30·6′ | 046·92° | 1245·22 |
| 4 | 20° | 18° 52·9′ | 048·36° | 1634·19 |
| 5 | 25° | 22° 54·6′ | 050·14° | 2004·20 |
| 6 | 30° | 26° 33·9′ | 052·24° | 2353·90 |
| 7 | 35° | 29° 50·3′ | 054·60° | 2683·15 |
| 8 | 40° | 32° 43·9′ | 057·20° | 2992·76 |
| 9 | 45° | 35° 15·9′ | 060·00° | 3284·14 |
| 10 | 50° | 37° 27·2′ | 062·97° | 3559·08 |
| 11 | 55° | 39° 19·4′ | 066·07° | 3819·54 |
| 12 | 60° | 40° 53·6′ | 069·30° | 4067·54 |
| 13 | 65° | 42° 11·2′ | 072·61° | 4305·07 |
| 14 | 70° | 43° 13·2′ | 076·00° | 4534·03 |
| 15 | 75° | 44° 00·4′ | 079·45° | 4756·28 |
| 16 | 80° | 44° 33·7′ | 082·95° | 4793·56 |
| 17 | 85° | 44° 53·4′ | 086·47° | 5187·60 |
| 18 | 90° | 45° 00·0′ | 090·00° | 5400·00 |

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KEY WORDS

1. Geodesy.

# Fast-Ferry Navigation

Dag Pike

Recent accidents to fast ferries, notably that to *Sea Cat* in Norway, have concentrated attention on fast-ferry operations, and the navigation of this new generation of fast craft. The *Sea Cat* accident was a navigation error which resulted in the vessel running on to rocks with the deaths of two passengers, and brought into sharp focus the risks which can be inherent in fast-ferry operations. It is suggested that prior to this accident there have probably been many other navigation errors which have had the potential for serious consequences. This has prompted a look at the problems and limitations of current high-speed navigation practices and possible solutions to reduce the chance of accidents amongst the expanding fleet of high-speed ferries. This paper also proposes a method by which standards of equipment and performance could be established in order to provide a better basis for the evaluation of safety margins.

1. CURRENT TECHNIQUES. Much of the current philosophy of high-speed navigation has developed from traditional techniques supplemented by electronic aids. In many of the areas in which fast ferries operate the vessel is close to land, and is operating in narrow and sometimes congested channels. In many of these situations, pilotage techniques provide a viable solution to the navigation problem and indeed are the primary means of navigation. Although a higher degree of concentration is required at high speed for this type of visual navigation, pilotage techniques are generally adequate for the purpose when weather conditions are good.

At high speed, plotting positions on a chart in the traditional way is not a satisfactory form of navigation. The plotted position could be a mile behind the actual position by the time it is plotted, and so it becomes history, and not particularly relevant to current navigation. This type of manual plotting is not generally carried out on fast ferries.

An alternative can be found in the electronic chart, which provides a real time plot of the vessel's position. Although electronic chart technology has not reached the stage of development where it can replace the paper chart, it can be adequate for fast-ferry operations provided that its limitations are understood. This electronic plotting can provide a check on the pilotage navigation and it provides an excellent substitute for manual plotting. The radar can provide a similar check on position which is independent from other systems, although the radar presentation does require more interpretation than the electronic chart.

In good visibility, then, navigation tends to be based on pilotage as the primary means of navigation, with the electronic chart and the radar providing the essential checking facilities, so that the navigator can get confirmation of his position and the tactical navigation situation if there are moments of doubt in the pilotage navigation.

This method of navigation is reasonably adequate for speeds up to 40 knots. It leaves control and judgement fully in the hands of the navigator, which is probably the right approach in good conditions. The navigator develops his own safety margins, probably instinctively rather than by design, and it is only when conditions deteriorate through darkness or poor visibility that the existing practice is found wanting. It is significant that the *Sea Cat* accident happened in darkness, apparently because, during the darkness interval of a significant flashing light, the wrong action was taken. Currently, the characteristics of flashing navigation lights and their location do not take into account the requirements of fast-ferry operations.

It is in darkness and poor visibility, and perhaps to a certain extent in rough sea conditions, that the safety margins of fast-ferry navigation can be reduced to the point where the risks can become unacceptably high as far as current techniques are concerned, and where the navigator is left with little in the way of reserves for checking in the deteriorating conditions.

2. SAFETY MARGINS. Safety margins in marine navigation tend to be instinctive rather than mandatory as they are in air navigation. This has always been the traditional approach, and it has stood the test of time, but pressures are mounting for a change in attitudes. Mandatory safety margins have already been introduced in the form of traffic separation schemes, and some port approach systems, but in general, fast ferry operations tend to be governed by what the operator thinks is appropriate for the circumstances rather than by mandatory requirements.

This attitude persists despite the obvious conflicts which can occur in the mind of the navigator between the requirements of keeping to a time-table and the requirements of safe operation. On a larger, slower ferry the need to reduce speed, say from 20 to 15 knots, in the interests of safety will not have too significant an impact on the time-table, but a reduction from 40 to 15 knots would ruin the convenience of a high-speed ferry

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service. The reduction may not have to be quite so dramatic given the better manoeuvrability and stopping power of the fast ferry, but a fast ferry with its premium fares can quickly lose credibility if it does not adhere to the time-table.

So there are considerable pressures on the fast ferry navigator to maintain schedule. There is a further problem he has to face, which is generally of his own making, and that is familiarity with the route. This familiarity can lead to corners being cut, literally by passing very close to dangers without regard for the consequences of a propulsion or steering failure if it occurs at that point.

This apparent risk-taking by the fast-ferry navigator and the consequences of accidents which could result from it will inevitably lead to the introduction of mandatory safety margins for fast ferries. These will probably come as the result of accident enquiries, although it would be nice to think that the authorities are aware enough of the problems not to wait for an accident before introducing them.

The most obvious and easy way to enforce safety margins is to make the ferry follow a prescribed route. Such routeing could separate out ferries running in opposite directions and could maintain suitable distances from dangers such as shoals and rocks, and would certainly help to promote safe operation. Maintaining such a course is well within the capabilities of modern electronic navigation, but it might need some improvements to navigation marks for pilotage navigation.

Defining and enforcing a safe course is comparatively straightforward. It is a matter of lateral location, but much more difficult and contentious is to define safe speeds along that course to suit varying conditions. Traditionally, speed guidelines have not been laid down for marine operations except for the need to reduce speed in fog or poor visibility, but with fast ferries this need to define safe speeds could now arise in the interests of safety.

3. PROPOSED GUIDE FOR SPEED CONTROL. The concept proposed here is not so much to establish precise criteria for speeds in different conditions, but to suggest the sort of guidelines which might form a viable basis for establishing such a system of control. If certain conditions are met, the vessel can maintain speed – subject, of course, to the normal constraints which apply to all vessels. This concept is based both on the type of conditions which a ferry might experience during operations, and the equipment it should have on board in working order to enable it to cope. First, there will be a look at the requirements for navigation and then for collision avoidance.

(i) *Navigation*. The basis of what might appear to be a suitably safe system for fast-ferry operations is using the criteria of having two independent navigation systems which provide the navigator with real-time position information related to the vessel's track and to the surrounding dangers.

Pilotage navigation should meet the requirement for one of these systems when operating in conditions of good visibility. Both the electronic chart and radar could be alternative electronic systems, although there may be some doubt about the adequacy of radar unless it can differentiate between navigation buoys and vessels. Cross-track error and course and distance to go from a position fixing system would not be adequate, but it could be considered if combined with a suitable radar.

In clear weather and daylight, a fast ferry could have all three systems operational. This would give a measure of redundancy so that if one system failed, the vessel would still be equipped to proceed at speed. At night or in poor visibility, the electronic systems would become the primary systems, because pilotage would not provide adequate information. If both of the electronic systems were operational the vessel would be cleared to operate at speed, subject to the requirements of the International Regulations for the Prevention of Collision at Sea. Any equipment failure at this point would trigger a reduction in speed because there would be no independent confirmation of the navigation situation. The actual trigger points and relevant speeds would need to be decided in the light of the particular navigation situation.

Whilst it is accepted that this solution to fast ferry navigation places a high reliance on electronics, it is felt that electronics have now reached a performance level which justifies this reliance and, in the event of equipment failure, the system is fail-safe because speed reductions are triggered.

(ii) *Collision Avoidance.* Collision avoidance is a vital part of navigation and its poses particular problems for the fast-ferry navigator. When the situation can be assessed visually, there are no special difficulties and there is a tendency for the fast-ferry navigator to keep out of the way of all vessels. There is no basis in law for this action, but by putting the onus on the ferry navigator, it can reduce the problems some slower vessels have in assessing collision risks and taking avoiding action involving a fast-moving vessel.

The same action tends to be taken in poor visibility for the same reasons, but now the ferry navigator is having to assess the situation by radar until visual contact is made. Here, the risks are higher and there is a mandatory requirement to slow down, although the actual conditions when a reduction in speed is required are not specified. With the current level of radar technology, reducing speed is the 'official' action, but in practice slowing down can mean different things to different people, and it is not clearly defined in the collision rules.

With their shallow draught, fast ferries can avoid main shipping lanes in many cases, and this reduces the risk as far as shipping is concerned. However, this is also a favoured ploy for small craft, yachts and fishing boats, which do not always return a detectable radar trace, particularly in heavy sea clutter. Avoiding the shipping lanes could thus swap one problem for another.

For collision avoidance, then, the risks may be less easy to quantify and the statistical record is reasonably good. There is a requirement for a radar designed specifically for the requirements of fast ferries, and there is a need for a back-up in the form of a second manned radar if reliance is to be placed on the equipment. Radar can be supplemented by low-light TV and infra-red cameras, and there is a considerable amount of development work required if fast ferries are to operate at speed in poor visibility. The manning aspect should not be ignored, and if two radars are required they should be manned independently.

Collision avoidance for fast ferries is a complex area and, within the limits of current technology, the only safe option is to operate at speeds where the stopping distance is considerably less than the limits of visibility. In deciding safety margins, the authorities may want to extend this to a visibility which is at least twice the stopping distance, and then only when one or more collision avoidance radars are manned. Shore control of fast-ferry operations rather in the manner of air traffic control is another option, but this is only likely to be successful if it is extended to all shipping in the area and not just to the ferries.

4. CONCLUSIONS. Within the limits of current navigation technology and practice, it is possible to put fast-ferry navigation on a safer and more logical footing. The need for a more logical and structured approach has become apparent from the *Sea Cat* accident and a study of the way fast ferries operate at present.

The fast-ferry industry is comparatively young and is probably more open to change and legislation than the general shipping industry. Its approach is more akin to the aircraft industry in many respect, and as the number of fast ferries in operation proliferates, the need to introduce safety procedures and techniques is becoming urgent, with a new generation of larger, faster ferries (some with speeds over 50 knots) due to enter service shortly. Alongside the proposed changes there is also a need for electronics manufacturers to address the particular needs of the fast-ferry industry in order to enhance the electronic navigation capabilities of fast ferries.

KEY WORDS

1. Fast ferries. 2. Electronic charts. 3. Radar. 4. Pilotage.

# Reduction to Final Speed: A Simple Formula

Adrian Burnett

In a recent issue of the *Journal*[1] Captain Fales discusses the question of achieving an accurate arrival time concomitant with fuel economy. He proposes a method of monitoring permutations of speed by the setting up of simultaneous equations. Whilst agreeing with him, I believe the following alternative presentation of the problem makes the computation more intuitively appealing, and considerably more accessible and therefore useful to the average operator.

Firstly, the question of differentials in operating speeds extends beyond simple fuel economy to include ships with combination propulsion systems, typically warships. The considerate navigator of such a ship will co-operate with his engineer to plan passages in such a way that life cycles of gas turbines, as well as fuel economy, are taken into account. Even a short passage can present an alarming combination of possibilities; therefore the simpler the sums, the more satisfactory the result. Although graphing this sort of problem is useful, the results are never accurate enough, and they have to be re-worked by another method to achieve precision.

Warship navigators also face another problem unknown to the merchant navigator – namely that of getting a large and varied group of ships through pilotage waters and into harbour in some degree of order. Although the mathematics of this are identical to that of the single ship, the activity level involved in managing a formed body of ships is high, and the consequences of a mistake are embarrassing and public, especially when 'showing the flag' abroad. Again therefore, the most blunder-proof possible approach is indicated.

Simple though simultaneous equations may be at the classroom desk, they change from Jekyll into Hyde when the navigator is trying to write night orders for the formation commander at 2200 on a busy bridge. Is $x$ the higher or lower speed? Shall I allow for tidal stream and if so, where? How much slack do I want? These are all questions which beset the navigator at a time of pressure. The chances are that, once he has got a result by simultaneous equations, he will not feel inclined to re-work the whole thing to check it or, if he does, he will make the same mistake again. Even more importantly, the humble Officer of the Watch, entrusted with overseeing the night orders which will ensure successful arrival the next day, will be so put off by simultaneous equations that he will evade conscientious checking and monitoring, and will rely on the navigator's brilliance to carry things through. This belief in the navigator's infallibility usually presages a disaster of far-reaching proportions. However, given the simple formula