probabilities. In finding an M.P.P. he uses his fix (or position line) and his D.R. position, and as Mr. Durst's findings suggest that the D.R. position is generally extremely inaccurate when compared with the fix, the outcome of the rather cumbersome M.P.P. construction would be to place the final position so close to the fix as not to make the labour worthwhile. But if, as Mr. Palmer suggests, we use a very careful wind to determine our D.R. position, the latter will become more reliable, so that there may after all be a use for the M.P.P. The two techniques are in reality closely similar.

The fact that, according to Mr. Durst, D.R. error is about twice what it was previously thought to be, is a sobering thought, and should encourage us to re-examine our procedures closely. It is hoped that more navigators will come forward to give their views on how this new knowledge can best be applied in practice.

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The Time-distance Radar Plot

from Captain F. J. Wylie, R.N.
(Director, Radio Advisory Service)

DR. ATKINSON puts up an interesting hypothesis* which I hope will not appeal to many sailors, because I do not think it offers what the navigator needs and I believe that it could be misleading. As far as concerns other plots discussed in the *Journal* or *The Use of Radar at Sea*, the criticism that they do not use all the information available is, I think, quite invalid.

Comparing the advantages (*a*) to (*f*) which he claims for the time-distance plot with a relative plot drawn on the kind of instrument described in *Journal* Vol. VIII, page 76, I would say that:

(*a*) As far as ease and speed of operation are concerned, there is little difference between the time-distance and the relative plots.

(*b*) The relative plot gives more information in a more obvious way.

(*c*) The relative plot will give equivalent information in exactly the same form; I can see no virtue in the fact of giving precisely the same information to both ships.

(*d*) I don't believe that instinct will be as valuable in dangerous situations as intelligence, and in any case, it is not true to say that stopping will always avert a collision. I also disagree that the instinctive turn is 'away'.

(*e*) I must disagree that it is the easiest plot to teach, because I believe that the majority of navigators will require information rather than a rule of thumb. Plotting can be taught without the use of obscure phrases and if this is done the sailor will not find anything very different from his experience of the

* Atkinson, R. d'E. (1955). The time-distance plot. This *Journal*, **8**, 211.

problems of relative motion on which he has grown up. From what I have learnt of Merchant Navy reactions, the navigator who does not plot is not put off by the 'complexity' of any particular kind of plot; either he thinks he can do better without a plot, or he does not consider that any time can be spared from his other duties.

(*f*) If a 'cheaper set' refers to the radar equipment, it must be remembered that the equipment is required for purposes other than avoiding collision.

The real disadvantage of this kind of plot, however, lies in the fact that it cannot add anything of value to one's information in the early and vital stages of an encounter; it suggests, quite wrongly I think, that the only important characteristic of danger is its rate of approach. I can explain this with a simple example: an echo is observed 20° on the starboard bow at 10 miles and it closes to 9 miles in three minutes. If the ships are on collision courses, the time-distance plot will be a straight line which will reach zero distance in 30 minutes.

Supposing that the other ship had been steering so as to cross ahead with a closest approach of 2 miles on the port bow, the time-distance plot would have been almost identical with that of the collision course case until 15 minutes after the start of the plot, at which time the distance is halved. Even at this stage, all that the time-distance plot will tell one is that there might just not be a collision and that there might be not much more than 17 minutes to go before the nearest approach. If the other ship had been steering so as to approach not closer than 4 miles, it is unlikely that there would be any certainty that the ship was not on collision course until 12 minutes from the start.

In these examples the bearings of the ships which were not on collision courses would have altered more than 5° considerably before any reliable indication of curvature would have occurred on the time-distance plot. I am quite sure that to omit bearing is bad psychology as far as mariners are concerned; the bearing is second nature. Had the information in these two cases been put in the simplest possible way on a relative plot it would, a long time before this, have shown the direction in which the other ship was moving and the distance off at which it would pass.

The main point of this criticism is that the information from the time-distance plot comes too late and when it does come it gives no indication whatever concerning the other ship's heading and no guidance as to the best avoiding action, both of which subjects are of immediate concern to most sailors.

The mariner, on the whole, does not wish to get himself into positions in which he has to stop. With the time-distance plot, this seems to be as inevitable as if the two ships were railway trains closing on the same track.

If ships take avoiding action, they usually want to take it early in the approach. When they do so the rate of approach almost certainly will alter and it is quite likely to increase. It is imperative then to be able to discover whether the new relative motion is due partly to alterations of course and/or speed by the other ship. The time-distance plot will not help in this.

In reply to Captain Wylie, Dr. Atkinson writes:

Captain Wylie's comments are naturally entitled to the most serious consideration; but I doubt if our points of view are quite as far apart as he evidently feels. I agreed in my paper that fuller information could be obtained by the more elaborate plots that are in limited use already; and he agrees that one important reason why these 'orthodox' plots are not in more general use than they are, is that many Merchant Navy navigators have not enough time. The question whether the time-distance plot is quick enough for them to use would I think be best settled by trial; but meanwhile my own feeling is that while Captain Wylie's admirable plotting device will certainly facilitate making a relative plot, and will allow quite rapid work after very little practice, the operation will still remain appreciably slower, and intellectually more exacting, than the one I have proposed. I suspect, also, that all such devices have a slightly deterrent psychological effect on the man who has so far not plotted at all, even though they are rightly welcomed by the man who has; the time-distance plot is so simple that I believe it may really 'lure more masters into plotting', and this would be a positive gain.

The numerical example which he gives can be worked out in some detail. Closest approach occurs at 28·74 minutes, when the other ship is 58° 28′ off the port bow, and the data are sufficient to compute the time-distance plot completely. I agree, of course, that at 15 minutes it is still pretty straight; but the 'time left' is still not down even to the largest limit I suggested (12 minutes), and by the time it does reach that value it is decreasing only very slowly and is clearly going to turn up before long. It never does get as small as 8 minutes (the minimum being 10·5 minutes, if one uses three-minute chords), and on the whole I think one might say that this is not quite a 'stopping' case. Would Captain Wylie accept a prospective closest approach of perhaps 2 miles as definitely safe, in the *early* stages of this encounter, or is it a borderline case for him also?

I agree, of course, that in the later stages the bearings give a great deal of additional information; but I did suggest that one should write down the bearings too and see how they are going, and I did say that they would usually give earlier information that the danger had passed than the time-distance plot can. In view of Captain Wylie's remarks, I feel that I ought to have stressed this aspect more than I did. But although I agree that the bearings are extremely valuable, I doubt whether it is necessary actually to plot them; certainly in the present instance it does not seem so. At 15 minutes, the bearing has changed about 12°, and the ship is now only 8° on the starboard bow; she is still about 5¼ miles distant and is evidently going to cross quite soon; and well before the 'time left' has reached its minimum, she actually does cross, over 3¾ miles ahead. I think it might be difficult to 'sell' any plot at all to a short-handed merchantman, in this case; at most a very rough time-distance plot, with two or three bearings entered on it at any odd times, will be enough to show that there is a reasonable margin of safety. If, however, the bearings do not develop a reassuring swing, the plot gives an immediate numerical criterion for the degree of danger which, so far, is still present.

Captain Wylie says that if one uses a time-distance plot one will 'inevitably' go on until one simply *has* to stop. This is, I think, a little unfair. The navigator who uses this plot is no more tied to 'railway tracks' than any other, including the navigator who does not plot at all, and I myself stressed that it would be better to take early avoiding action. The point is that if this has not been done, and if a situation has arisen where the safest thing that still can be done is to stop, the time-distance plot will shout this aloud, undeterred by the effects of such futile last-minute turns (by *either* ship) as I instanced. Its primary purpose was to prevent disaster when things have not gone as one had hoped or expected, and I think it does this. It is, of course, true that one can devise situations in which it is wrong to stop; but I have not myself found one in which it was wrong to stop although the plot said so, except of course very nearly head-on approaches, where one would more naturally have turned aside fairly early. Apart from those cases, I think stopping will produce a collision only in situations where it is already reasonably clear that the other ship will cross astern if one does not stop; but I will concede that this will perhaps not always be clear enough unless one does watch the bearing too. (Any ship whose compass bearing is increasing, if she is to starboard, or decreasing, if she is to port, will cross astern if she crosses at all.)

Even the most complete plot cannot tell you what to do if the other ship is just about to do something unknown herself—as seems not unlikely, on the whole. I think, though, that there can be very few exceptions to the statement that if the bearing has been strictly constant there will be a rapid improvement if either ship turns (more or less) towards the other; there is the important proviso that it may be disastrous if both turn so, but this can be prevented by a rule against turning to port. The first effect of a turn 'towards' may well be an increase in the rate of closing; but the plot will now be curved and not straight, and the time left will soon be visibly increasing. Captain Wylie's statement that, if a ship takes suitable avoiding action, an increase in the rate of closing is quite likely, evidently implies the view that turning towards the other ship can often be the proper thing to do; for there is no other manœuvre (except an increase of speed) which can ever increase the rate of closing. We seem therefore to be in agreement on this point also.

Finally, I believe that so long as it is still doubtful whether the bearing is or is not changing, no plot can add much to what the time-distance plot says, namely that you are headed for a collision, or a fairly near miss, after a time-interval which is directly apparent, and at a distance, dead ahead, given by the product of this time and your own speed. I will even claim that in these important cases the time-distance plot, properly used, gives the clearest picture one can get. The two ships and the point of collision form a triangle for which one actually has two sides and the included angle (range and bearing to other ship, and computed distance to collision); the other ship's speed and course are directly given by the length and direction of the third side, and I think one could usually visualize this 'absolute' plot quite clearly enough for action without even putting it on paper at all, and that it is better than a relative plot. In Captain Wylie's example, for instance, the position after the second observation is that the ship is 9 miles away and nearly 19° to starboard; the 'time left' is 27 minutes; and both ships are therefore approximately headed for simultaneous arrival at a point $27v/60$ miles ahead of own ship, where v is own speed in knots. One needs no plot, I think, to realize that if v is 10 the other ship is coming in at something over 45°, with a speed comparable to one's own or a little more, while if v is 20 the point of collision is as far away as the ship and she is coming in at a little more than square and is nearly three times slower than own ship. Even though the bearing really did change a little, between the two observations, these conclusions are pretty close to correct, and are certainly quite good enough to let one decide one's early avoiding action. I think they are more rapidly reached from the time-distance plot than from any which needs two bearings before it can be constructed. If the change of bearing is indisputable at even the second observation, a 'conventional' plot will no doubt give more accurate information; but those are just the cases where one does not need it.

The following comment has been made on the time-distance plot by Commander B. C. G. Place, V.C., R.N., (H.M.S. Tumult) as a result of using it on a (limited) number of runs at sea:

(1) The plot of the first few ranges always indicated a collision was possible, and it is therefore necessary to use bearing in conjunction with this plot. (One ship's contact altered 15° of bearing before there was a noticeable tendency for the time-distance plots to be other than a downward sloping straight line.)

(2) Before an alteration of course—either navigationally or for avoiding action —I can see no way of using the plot to determine whether the alteration will bring own ship into danger of collision with another ship being plotted.

(3) Radar gives bearing and distance: time is always available. Surely the best plotting system is to present bearing (within the accuracy limits), distance and time on the same plot which can then be used to solve any problem. Presenting time and distance only limits the information you can get from such a plot. As the mariner is so used to bearing—and necessarily relies on it when steaming without radar—I see no logic in not using it as an integral part of a basic plot.

Captain D. Daragan, C.B.E., (late Russian Imperial Navy) writes:

When reading attentively the April issue of your *Journal*, I was struck by a sentence in Dr. R. d'E. Atkinson's remarks, namely the following: 'You each know the distance, of course, and you both know it correctly, but neither of you know your bearing from the other ship's point of view'.

Well, if these ships know their reciprocal distances let them inform each other of their relative bearings or, simpler, of their true courses. I would like to suggest that the following method should be used, provided both ships have r.t. or something similar: let us suppose that ship A is equipped with radar and uses a 10-mile scale. There may be different ships' echoes on the PPI, but as soon as one of the echoes from ship B reaches strictly the 9-mile range (or some other range, which should be fixed internationally), ship A telephones her true course and her relative bearing of ship B. If B has a radar and r.t. and the radio service is well organized, ship B who should have noticed on her PPI ship A at the same distance of 9 miles (plus or minus some difference due to delay in transmitting the information) telephones immediately her course and bearing of ship A. If this should happen—the whole question is solved and ships A and B have identified themselves. If ship B is inattentive and does not hear the information of A, nothing happens, but the situation will not be worse.

One must admit that there are ships with radar which will not get an echo of another ship at 9 miles' range. I would suggest that the same procedure should be repeated let us say, at 5 or 6 miles. All these questions about the fixing of suitable ranges, manner of transmitting of courses or bearings &c., must be discussed by a suitable organization and officially accepted, but the principal point is the possibility of using the distance between ships and giving short mutual information of simultaneous bearings and courses of each ship. It is difficult to imagine that there will be several ships at the same time at precisely the same distance from each other; but even in this case, if the first piece of information is not quite clear, the following one will certainly give the expected reply to both ships concerning their reciprocal positions.

I have suggested making r.t. contact at some fixed distance; but another method could be used. If there is an echo from a ship which 'interests' you,

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you can begin to telephone: 6½, 6½, 6¼, 6¼, 6 . . . (your range to the ship) and the other ship, if she has radar and r.t., will reply by confirming the range (if necessary) and state her course or bearing. Thus the contact and identification will be reached.

Captain F. J. Wylie, comments on Captain Daragan's letter:

There are, I think, two problems in Captain Daragan's suggestion, one is a difficulty and the other a danger. The difficulty lies in being certain that the voice you hear on the radio-telephone is coming from a particular echo on the PPI. His method presumes that all ships would be on the same radio-telephone frequency and hence that all ships within, say, a 20-mile circle of any particular vessel would be within radio range of her. As soon as an echo was on the '9-mile range', at least two ships would begin endeavouring to get out their signals, and it is hardly possible to avoid the expectation that other ships in radio-telephone range would have echoes near enough to 9 miles to be just ending or beginning similar transmissions. Two or three minutes' delay and one or two other reports would introduce all the uncertainties which this scheme is intended to remove. This introduction of new uncertainties is, in my opinion, at the root of all suggestions of this nature so far examined.

The danger lies in the fact that a statement about a course being steered is almost as much retrospective as a course deduced from a radar plot. In the mind of the careful seaman there can be no certainty whatever that the ship will continue to steer it or that she will report when she changes it.

Dr. R. d'E. Atkinson comments:

The risk of confusion, which Captain Wylie stresses, is very real, and is inherent in most existing proposals for obtaining 'first-hand' information about the course and speed of a ship seen only on the PPI. But Captain Daragan's proposal has now suggested to me a procedure which may I think overcome the risk almost completely; for although one cannot tell (without plotting) what one's bearing relative to the other ship's head is, the distance is definitely not the *only* item of precise information which both ships have in common, if they are using radar. They both know the compass-bearing of the line joining them, as well; and if they wait for a second observation, they both also know their net rate of closing, and the rate of swing (probably small, though) of the line joining them. This should provide more than enough 'pass-words' to check whether one is listening to the ship that one supposes, if a ship should speak out of the fog; and in addition she could beam her remarks towards one. It should be relatively simple, if one sees a pip at (say) 9 miles, 047° magnetic, to beam a (short-range) transmitter towards 047 magnetic, and morse '09227' (i.e. 'I am the ship which you see at 09 miles, 227 magnetic'), followed by a similar group giving own speed and compass course. Morse is, admittedly, rather slower than speech, but it is international, and quite fast enough; if it was received by a signaller, there would have to be arrangements for passing the message to the navigator promptly, but that should not cause difficulty. As far as the transmission goes, an automatic transmitter could be fed with own course and speed from time to time, and could have the bearing which it transmits keyed permanently to the bearing towards which it is pointed; all one would then have to do is to set to the bearing and distance which one sees on one's PPI, and switch it on, say for a minute or less. It can very seldom indeed happen that there would be a second pair of ships, also nine miles apart, also on a 227-047 bearing from each other, and also within the beam of this transmission; and in order to prevent the two ships which are concerned from talking at the same time, one might have a convention that the more northerly, or westerly, of the two will speak on the even minutes of G.M.T. and the other on the odd ones. At first contact, the bearing would usually be changing pretty slowly; the distance would not have to be very precise if the bearing was nearly right; and the nearest minute should be quite near enough for identification. It would still be possible that one was spoken to by two ships at once, and even more possible that one could hear two ships at once, without being addressed by both; however, moderation all round would keep these cases down, and one might also consider making one's receiver directional if necessary. A further possibility would be to have a (directed) 'asking' signal, combined with a directional receiver, and to have a rule that if traffic was heavy one would not speak unless asked to do so.

It would seem possible, by such means, to be told quite reliably what a ship was doing, many minutes before plotting could give any useful information; thus any ship which fitted and used such gear might have a reasonable hope that other ships would be glad to take the necessary steps to avoid her at a very early stage, while she kept on her course. If she did prefer to take action herself, there would be much less need to take extremely pronounced action, if she announced the change directly.

Early Pole Star Tables

from Lieutenant-Commander D. W. Waters, R.N.

I CANNOT subscribe to Dr. Freiesleben's thesis that until the French Revolution induced a change of mind there was a big gap between men of science and seamen.[1] It may be, as he states, that 'in the eighteenth century there was still a remarkable gap between scientific doctrine and practice' and it would be interesting to know the causes if this were so, but in the sixteenth and early seventeenth centuries there was, particularly in England, a quite remarkable and organized liaison between scientists and seamen with the specific purpose of improving the art of navigation. The object, as Thomas Digges expressed it in 1579, was 'to reduce Imaginative Contemplations to Practical Conclusions'; in other words, it was to make scientific discoveries and inventions to improve the accuracy of navigation.[2] A few examples must suffice in the space available to support this statement.

Dr. Freiesleben notes 'that Nonius and the German cosmographers give the distance of *Polaris* from the Pole as 4° 9′, whereas the contemporary seamen knew the correct value to be 3½°', and cites this as illustrating 'the estrangement between scientific doctrines and practical experience' at sea in the sixteenth century. The reverse is, in fact, the case. In 1545 Martin Cortes completed his *Breve Compendio de la sphera y de la arte de navegar* (Seville, 1551) and specifically included Johann Werner's polar distance of 4° 9′ in preference to the 3° 30′ in current use by seamen as he supposed it to be more accurate.

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