the spheroid and the textbooks devote a few sentences (not invariably accurate) to the subject. Small wonder that the curiosity of any intelligent student is further aroused.

On Mr. Tyrrell's main point, mathematical tables enabling navigators to work accurate spheroidal sailings by either mercator or mean latitude methods (slightly modified) are perfectly practical and have been discussed technically elsewhere. The mean latitude method would probably differ in minor detail from Mr. Tyrrell's proposal for technical reasons and the mercator method is given in the latest edition of Burton's 5-figure navigation tables. When a sufficient number of navigators consider facilities for spheroidal sailings to be a requirement, they will have them.

Air navigators prefer plotting to calculation. Here the solution is simplicity itself. On the mercator (or any conformal projection of the spheroid) it is merely necessary that some meridians be graduated in nautical miles instead of minutes of geographical latitude—these scales being used for distance measurement by the standard method for orthomorphic charts. This is not a radical departure even for our conservative profession.

Returning to the question of training. I think students should appreciate more clearly that the function of mer. parts for the spheroid is merely to keep the *right proportion* between chart length of 1′ long. 1′ lat., so that conformality is retained and angles are correct. The fact that 1′ *d.* lat. is not precisely 1 nautical mile, a more or less arbitrary unit of length, remains. If the spheroid is mentioned at all the student should comprehend that, in consequence of the above, the formulae dist. $= d.$ lat. sec course or $d.$ lat. $=$ dist. cos course are as inaccurate as ever, and that in some cases a sailing calculated by mer. parts for the spheroid is in fact in greater error than a simple spherical treatment. I have never understood why some tables designed for the use of navigators give spheroidal mer. parts with no other concession to the form of the Earth.

The Accuracy of Dead Reckoning in the Air

from W. Hudson

I WAS unable to attend the lecture by Mr. C. S. Durst on 'The Accuracy of Dead Reckoning in the Air', and I was, therefore, very interested to read the paper in the April *Journal*.[1] There are many implications, and Mr. J. B. Parker has endeavoured to suggest some in his article.[2]

It is good to see his definition of dead reckoning; I have often wondered what it means in the subconscious minds of some navigators—perhaps a method of avoiding the necessity of acquiring more accurate information. To me it is a technique not without its uses and certainly not without its fun, but to be kept to the minimum by regular and definite findings. I believe that is the way of most professional navigators.

Mr. Parker concludes with a summary of problems to be reviewed. Various military drills have laid down from time to time requirements for navigators

(mainly trainees) to obtain a number of fixes, winds, D.R. positions &c., and to check safety heights, compasses, heading and so on. The idea is very good but has its limitations, for various items may be logged whether they are checked or not: 'cooked' is the word. However, a developed routine is a useful asset, and forms the background to the work of the practical navigator. Whether the practical and experienced navigator utilizes the many findings listed in text-books on average errors for D.R. positions and most probable positions is another matter.

The practical answer to the summary therefore might read as follows:

(1) *Track keeping*. Information obtained as and where required. The navigator is content to know that he is on track and that his timing is satisfactory; in other words, his fixing rate is adjusted to the circumstances as he sees them.

(2) *Search and rescue* is always a difficulty. Perhaps the answer is in improved locating methods. Steps are continually being taken in this direction.

(3) *Safety heights*. Bands and cones of possible error are unwieldy. The navigator and his captain must know the height of the highest ground in the vicinity of which the aircraft is flying at any particular time. Accurate fixing and altimeter setting, and regard to safe clearance, are essential.

(4) *Finding the island*. 'Deplorable' according to D. C. T. Bennett, and one must agree!

(5) *M.P.P.* Justifiable in certain conditions. The navigator will prefer to use his own figures based on his own opinions of the worth of position line or lines, and D.R. position. There is sometimes an indefinable something, a feeling, or almost a hunch, that helps.

(6) *Fixing rates* See (1).

(7) *Wind utilization*. The met. wind is not always accurate, but the forecasts and charts are always useful, and the found wind may be adjusted in the light of available met. information.

Mr. Parker states that the various factors differ from user to user, and this is so. The navigator will read Mr. Durst's paper and will, perhaps, make slight adjustments to his technique where necessary, and meanwhile look forward to further progress in the subject.

from E. Palmer

Mr. Durst's paper [1] is highly interesting, and I would not dream of arguing with his mathematics, but I suggest that the deductions that he draws, and the implications suggested by Mr. Parker, [2] do not follow and do not correspond with practical experience.

The conclusions appear to be based largely on standard errors, in which the occasional hopelessly inaccurate wind forecast tends to disappear, lost in the greater number of occasions when the forecast is reasonably good. But that is the occasion when almost invariably the found winds are of far greater accuracy, and the forecast can be thrown into the wastepaper basket half way along the sector. It seems that under certain conditions Mr. Parker would have us 'use met. winds as a matter of course', and not bother to find winds at all! Put into practice there would be three possible results, all of which would be obtained from time to time.

(*a*) One would arrive at one's chosen destination, but very much later than necessary.

(*b*) One would arrive at a destination other than that required.

(*c*) One would not arrive at all.

The habit of experienced navigators is to arrive within ten miles either side of their destination, and within five minutes of their E.T.A. using found winds, sometimes as future winds, but more often as a component of their idea of the future wind, taking into account the synoptic situation and what has been discovered in flight. There have been occasions in my experience, when, had I utilized forecast winds, I should have been upwards of an hour out in E.T.A. and others when I should have missed my destination by upwards of 150 miles. Therefore, I am afraid that if any meteorologist attempts to tell the average experienced navigator that forecast winds are almost invariably more accurate than those he has found and used (remembering that an accurate fix is rarely unobtainable, and normally when one is suspected to be inaccurate, it may be discarded, and the airplot carried on until a better fix is possible), I fear he is in danger of receiving a sharp answer.

A word or two on compass accuracy. Airplot inaccuracies are derived less from compass inaccuracies, and more from the inaccuracy of the autopilot or the manual flying as the case may be. Variation setting correctors are seldom used on civil aircraft, and are more nuisance than they are worth, unless of course an API is carried. Compass swinging merely reduces the error to acceptable proportions, and it should be clear that deviation errors remaining, due to the causes given by Mr. Fox in the discussion, should not affect the accuracy of the D.R. The actual compass error (a combination of deviation and variation error), is found by astronomical means in flight, and applied to give the true course. I should think that the error remaining after that normally ought not to exceed one degree, when the periscopic sextant is used—slightly more in the case of the old astro compass.

I would suggest these answers to Mr. Parker's questions:

(1) *Track keeping by increasing fixing rate.* There are limits to this obviously, but accurate track keeping often does not matter very much on sectors where classic fixing procedures are necessary.

(2) *Safety heights.* Aircraft still hit mountains (even in Europe). The band or sector might be varied according to the state of the navigational aids, both in the aircraft and on the ground.

(3) *Finding the island.* Homing down a transferred position line is hardly ever necessary these days.

(4) *An M.P.P.* seldom tells the navigator anything really worthwhile.

(5) *Fixing rates.* The higher the wind speed, the higher the fixing rate desirable.

(6) *Wind utilization to give D.R. position.* I would say emphatically practically always use the found wind, or a combination of the forecast and found wind depending on circumstances. The forecast wind alone should be used only when the navigator has very grave doubts as to the reliability of his fix—not a very frequent occurrence.

For the future wind, I use the found wind as a basis, modifying it according to circumstances and all the information available, i.e. original forecast, amend-

ments received in flight (a rare occurrence), weather experienced, surface wind velocities, and winds passed by other aircraft.

Mr. J. B. Parker comments:

It is with some diffidence that I rise to defend Mr. Durst's deductions and my own article on the navigational implications of his paper. Wearing two hats, the flying helmet of the navigator (now, alas, hung up for good) and the mad-cap of the statistician, I have the fullest sympathy for the views of Messrs. Hudson and Palmer, as they fit in so well with my own more limited practical experience.

I cannot accept, though, that neither Mr. Durst's nor my own deductions fail to follow from the data. If this is so, I hope the flaws in our reasoning will be set out in later correspondence. The fact that the standard error of a met. wind is less than that of a found wind does not of course mean that the met. wind is *always* the more accurate; but on balance it is. Does not this mean that, in operations, greater weight should be attached to the met. wind?

I do, however, plead guilty to the second of Mr. Palmer's charges. There is a misleading statement in para. 8 of my article, where I advocate, by inference, 'eliminating the classical wind-finding technique'. In the sense that this means attaching greater weight to the met. wind, this is all right, but the use of orthodox methods as a check should not be cast aside. This was a hasty, and, incidentally, a most non-statistical remark! As regards the charge that our deductions do not correspond with practical experience, I can only answer that the basic data were obtained by practical navigators, and that the statistics concerning the variability of meteorological forecasts have been carefully built up by qualified meteorologists in the Air Ministry.

Practical experience can be a misleading guide. We tend to forget the occasions when our own wind was seriously in error, but remember the times when the met. wind was 'duff'. The Institute's working party on the accuracy of observations at sea has shown that many navigators, whose 'practical experience' told them that their sights were accurate to within half a mile, were in fact getting much larger errors. Likewise, the air navigator who boasts that his astro sights are 'practically always within 5 n.m. and hang the 50 per cent figure' is not really on firm ground unless he has systematically checked his own astro accuracy (in the air, of course) on a great number of occasions against an independent and more accurately known position. How many of us do this?

Mr. Hudson appeals for a revision of practical experience in the light of fresh knowlegde, and there is no doubt that this continuing policy is the right one. Instead of blindly accepting the statistician's conclusions, or of resolutely dismissing them as being inconsistent with our practical experience, we should try to reconcile the two. Mr. Palmer's idea of compounding the two winds (also mentioned by Mr. Durst) in proportion to their reliability, is in the spirit of this middle approach, though Mr. Durst's paper suggests that the met. wind should usually be given the greater weight. It is strange how many navigators support such schemes, yet run away from horror at the idea of compounding their fix with their D.R. position. What is the logical case for finding a most probable wind but shying off a most probable position?

The case seems to be this. In finding a 'modified' wind the navigator makes use of several pieces of information, each of which has an appreciable weight in determining the final outcome. That the weighting is not mathematical but subjective does not alter the fact that the process is essentially a balancing of

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.

REFERENCES

1 Durst, C. S. (1955). The accuracy of dead reckoning in the air. This *Journal*, **8**, 91.
2 Parker, J. B. (1955). The navigational implications of Mr. Durst's paper. This *Journal*, **8**, 113.

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.