to the R A F may or may not ease the situation One is inclined to think in fact that the present system might break down, imposing intolerable delays The solution might be in the use of a navigational aid permitting smaller horizontal separations, but this is a matter for the specialist

The metropolitan operator is likely to be tolerated in Control Zones only below say 500 ft in limited lanes Tolerated, that is to say, by the Controllers , local residents might be most intolerant

Conclusion

The term " Navigation " has been interpreted fairly widely to include some operational problems—the two are in some cases hardly separable Inevitably consideration of such problems at this stage must be frankly speculative, and I hope that this lecture will stimulate comments and suggestions

I must acknowledge my indebtedness to the B E A helicopter pilots with whom it was such a pleasure to work on the experimental investigation of D R Navigation and also the assistance I have received from discussions of the subject matter of the lecture with a number of individuals, mainly in B E A I should like to thank, too, the members of the Fairey Aviation Company who helped in the preparation of the script and figures for publication The opinions expressed are my own and not necessarily those of the Directors of the Fairey Aviation Co , with whose permission I give this lecture

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Discussion

Mr G M Macintosh (*Deputy Director of Control and Navigation (Development), Ministry of Transport and Civil Aviation*), who opened the discussion, said the Chairman had carefully named the speakers, so that they had no excuse not to speak, and then had switched out the lights so that there was no opportunity to make notes ! Mr Macintosh had been up in a helicopter only twice and had been baffled on each occasion , he just about understood how they got up and stayed up, but anything else they did was not clear to him

Mr Davies had dealt with the subject admirably However, he has said, " A choice has yet to be made between the type of aid which provides a fix and the type which provides a radio range," which seemed to be simplifying the choice It was true that B E A had been using M F beacons and Decca, but they must also

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remember G E E, the hyperbolic fixing system and the R/Theta system Mr DAVIES had listed the various radio aids but had not mentioned VOR/DME It was a high frequency device which might not be good at low altitudes but it was a fixing aid and should be considered as such

The author had also spoken of the steep angle at which the pilot must descend through cloud What would that angle be ? Various values had been quoted, including something like 7 deg and it would be interesting to know what figure the Author suggested

References to the landing aid suggested that if they were not careful they would over-organise the helicopter out of existence before it started There was a tendency these days to make the business very complicated with many different types of equipment To his simple mind the appeal of the helicopter had been that it would operate rather like a bus Perhaps that was too simple, but if the helicopter were to have a radio aid at all—he would prefer it not to have one, but presumably it must have an *en route* aid—then it should serve the complete purpose The city centres to which helicopters would be operated would probably be run by local authorities, not the Ministry, and the cost of the approach aid would be very important He would hate to see the development of the helicopter impeded by requests for something which was too expensive No doubt it was difficult to break cloud with a helicopter because of its special control features, and it might be that Decca was not good enough, but Decca seemed to be suitable in every other respect—frequency, cover at low altitudes and accuracy—and it would be a pity if every effort were not made to see whether it would fulfil the approach function, too, in addition to the en route function

Was it absolutely necessary to break cloud in the way which Mr DAVIES suggested ? It seemed to create about the most difficult flight conditions Would it not be better to use Decca and to modify the approach technique until it was more akin to that of the ordinary aeroplane ?

Mr DAVIES suggested that the airways system had been developed and was available only to civil traffic In his official capacity, Mr Macintosh could not let that pass, in fact, they always tried to provide a national airways system Military and other aircraft flew on the airways, and the system was certainly not set up as the preserve of civil aircraft Although there were difficulties with our own Air Force, members would be surprised to learn the total number of military aeroplanes which flew on clearances on the airways system, including aeroplanes of the American Air Force It should always be considered as a national airways system

Mr DAVIES' diagram had shown a fairly extensive airways network, and it appeared that he had also included the advisory routes Although they would like to see the U K covered to that extent, in fact it was not, the system was less extensive than that shown on the diagram

Mr DAVIES also suggested the allocation of a height band between 1,000 and 3,000 feet but went on to say that he felt that such a demand for air space was likely to meet powerful opposition That was a masterpiece of understatement ! Air space allocation was a difficult problem, and Mr DAVIES' aim could not be achieved in present circumstances

One sentence read was " In this case the helicopter is hardly distinguishable from a fixed wing aircraft until it enters the landing phase " Mr Macintosh wanted to know whether this was true, because most of the information received so far had indicated that the helicopter was a special beast which had to be treated specially If it could be treated as an ordinary fixed wing aircraft even in one of its phases, that would be interesting information

Mr DAVIES said about Northolt " The transfer of Northolt to the R A F may or may not ease the situation " What did that mean ?

Mr Davies interjected that he did not know whether Northolt would then be used as intensively as at the moment

Mr Macintosh said there was an arrangement whereby B E A would vacate Northolt fairly soon The conditions under which it would be used had been the subject of an inter-departmental agreement which it was hoped would provide a satisfactory solution

It seemed possible, he continued, that the Author had not given sufficient consideration to airspeed variations rather than to variations in yaw In ordinary D R navigation, yaw was not such a serious consideration as the ability to fly at a constant airspeed, and from some of the things which Mr DAVIES had said, it seemed that

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that was a difficult thing to do under certain conditions With the fairly low cruising speed of a helicopter, one supposed that airspeed errors would be quite serious

Another point not clear was the future crew composition of helicopters Would they be one-man devices or two-man devices ? It was important to settle that point before starting on the navigation technique, because it would vary according to whether there was a one-man crew or a two-man crew

Next, how easy or how difficult was ordinary map reading from a helicopter ?

Mr Davies said it was very easy

Mr Macintosh said he always lost himself in a car in such a populous place as London If a helicopter were approaching the South Bank, fairly low down, would it be easy to find the site ?

Mr Davies said the question did not arise as the Ministry forbade flying over London

Mr Macintosh asked whether the gyro-magnetic compass, which was now a first-class instrument, was not capable of application to the helicopter It seemed a pity if it were not, for it might add a good deal to the general ease of flying the helicopter I L S had been mentioned as a possible approach aid Would the rotor itself make the choice of a suitable aerial position difficult ? They had done a small amount of flying at Blackbushe, using a B E A helicopter and Decca radar, and they could claim reasonably satisfactory results from their limited experience From the approach point of view, it looked fairly promising

Mr Davies (*in reply*) said Mr MACINTOSH had asked so many questions that it would take a long time to answer them fully He would answer some of them briefly

He had no rigid views on VOR/DME or Decca , there was a lot to be said for both aids though VOR/DME used high radio frequencies with the likelihood of poor low altitude cover

Conflicting views had been expressed on the angle of approach, but 7 deg would be regarded as rather shallow , a steep angle would be more like 30 deg and possibly even as much as 45 deg The reason it must be steep was that the landing site in the centre of a town would be small and possibly surrounded by obstacles which must be avoided

It was not a question of his suggesting the most difficult type of let-down , that was forced on them Of course, with a larger site it would be a different matter , they could then come in at a more shallow angle and give the pilot an easier time

In his view, both navigation aids and landing aids were required Of course, the facility provided was linked with the traffic density they had in mind , in thinking of high traffic density, it was difficult to see how these aids could be avoided If they wished to fly into London in bad weather and land on a small site, he did not see how they could do without a landing aid On the other hand, under less critical conditions outside a control zone, where the same difficulties did not arise, there could be some modification of the requirements

Only experiment could show whether let down on Decca alone was satisfactory , if B E A could use it successfully, so much the better But with high-density sites, a great deal of difficulty might arise and they might need something more reliable which would also help with the local control problem

Mr DAVIES said he was interested to hear that the airways were not limited to civil aircraft , he had attempted to cover himself by saying that aircraft under M C A control could fly in them

The next question concerned the differences between helicopters and fixed wing aircraft and, as one who had comparatively recently joined the helicopter field, he felt that from a civil point of view the differences were sometimes exaggerated The helicopter was different in respect of its low speed flying qualities, but once it had left the take-off point it was just an aircraft proceeding from A to B If it were a civil aircraft, it would be carrying pay-load and aiming to waste the minimum of time There seemed no reason why en route control or control zone control should necessarily be different

All he could say about airspeed variation was that in the course of the flights to which he had referred they had taken a number of visual fixes, the ground speeds were quite consistent and the E T A s and overall errors were of such a magnitude compared with the fixed-wing standard that it appeared that the airspeed variations were fairly small

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As for crew composition, a 30,000 lb helicopter would probably have a captain, first officer and cabin attendant

Map reading had seemed fairly easy across country, but over large towns it might be more difficult

Mr Davies said he did not intend to imply that the gyro-compass was not suitable for use in helicopters B E A had used direct-reading compasses of the Kollsman type simple because they were already installed He had no experience of the gyro-compass Inherently it was a better instrument but he understood that at Boscombe they had had a great deal of difficulty in installing the G4 in the S51

With I L S there might well be siting problems and be favoured the modified G C A type of let down They had tried the Decca radar, which had given promising results, but the trial was not sufficiently extensive for him to say anything categorical

Wing Commander J L Mitchell (*Air Ministry*) spoke of his diffidence to take part in the discussion because his experience of helicopters was limited to a short flight in which they had managed to place some bedroom china-ware upside down on the flag staff outside the Bell factory

Mr Davies had covered the field very thoroughly, but Wing Commander Mitchell wanted to point out some differences between civil and military operation The military requirements could be roughly divided into three categories—first, air-sea rescue, although it might be termed simply " rescue " for it was not limited to work over the sea , secondly, maritime warfare of various types , and thirdly, support of the Army, either with freight and troops or in an ambulance role In all these requirements the emphasis lay much more on low speeds than was the case with the normal civil application in the bus role For that reason he asked Mr Davies to say more about behaviour, particularly in yaw, at very low speeds and at no speed, and also about airspeed errors low down on the scale These three requirements also demanded an ability exactly to position the helicopter There was a need of a fixing aid, perhaps of the hyperbolic type such as the Decca, or R/Theta

In the R A F they had had very good let down results with Decca on orthodox aircraft and they saw no reason why they should not let down just as accurately with Decca with these slow aircraft, if the stations were suitably sited It was possible to have a BABS type of let-down with the R/Theta type, on the DME element of the R/Theta, but either would provide cheap let down facilities which were probably accurate enough

The use of Decca provided a radio track guide, and if there were to be some element of D R error it seemed that in the air-sea rescue commitment on behalf of a civil aircraft unequipped with various homing devices, they would have to be able to navigate to a known geographical position, and Decca might be the only way, particularly around the coasts

Wing Commander Mitchell said he would also like to comment on the behaviour of radio aids in helicopters Referring to the trouble which had taken place on Babs from propellor modulation with the aerials badly placed, he wondered whether these modulation effects applied only to pulse radio or whether similar trouble could be expected from C W This might affect various types of aid which they would like to fit Did it affect H F Voice, using aerials on top of the aircraft ? They knew very little about this

In his view, Mr Davies had over-emphasised the general control problem at the expense of the helicopter problem In the R A F they were acutely aware of the difficulties of the civil organisation but when they compared that with the position at Washington National, Bolling Field, Andrews Field and Anacostia Naval Base, in America, it would be seen how little we knew in this country about traffic density

He thought they should talk more about the helicopter in particular and less about control generally There were difficulties, but it was pleasing to see that Mr Davies recognised that, providing the aircraft could enter the approach phase at a similar speed—perhaps slightly slower than the fixed-wing aircraft, it should be comparatively easy to fix the helicopter into the patterns

On the other hand, in this control phase we ought to exploit the ability of the helicopter to hover It was an extraordinary admission to say that they could not exploit that vital characteristic By all means fit the helicopter into the traffic pattern of approach, but also use its ability to descent at a steep angle

Mr Davies had said little about auto-pilot control although the R A F thought it to be essential, and believed that it would make hovering feasible with no great strain on the pilot

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As for the question of the final approach, particularly in small city sites, Mr DAVIES had said little about altimeter work and accuracy They might be compelled to accept a radio altimeter to ensure this desirable feature

The Author had suggested 300 feet as a bad weather minimum for helicopter operation, but Wing Commander Mitchell hoped that this could be reduced to 100 feet or less Three hundred feet was the sort of minimum used with ordinary fixed-wing aircraft and the helicopter ought to get below that In other words, they must exploit the helicopter's advantages more fully if they were to bring it into the bus role, to which they all looked forward

Mr Davies (*in reply*) said that the B E A investigation had not included low speed flight , navigation had in effect been considered at cruising speed only There was no doubt that air speed errors were large at low speeds Boscombe had calibrated the Bristol 171 down to 25 knots and at that level errors were increasing rapidly Undoubtedly large yaw might also appear at low forward speeds

He could offer little information on the behaviour of radio aids in helicopters other than the fact that V H F and Decca gave satisfactory performance

It might be true that he had emphasised the control aspect of the problem rather than the helicopter aspect, but his view was that the helicopter should not hover on entering the control zone It must get to its destination, and surely the flow technique was better than the hovering technique for this purpose Only at the destination did it become necessary to exploit the hovering ability

He had not mentioned auto-pilots because he had no direct knowledge of them, and he knew of no experimental work on them in this country If they could be incorporated successfully, by all means incorporate them

In the course of radar trials at Black Bushe they had tried to sort out altimeter errors It was rather difficult, but during descent at something like 800 feet a minute they had the impression of a lag of about 100 to 150 feet The lag of the vertical speed indicator was also pretty substantial He agreed that a radio altimeter might serve a useful purpose

The limiting cloud base was tied up with the whole question of the operation of helicopters If they designed helicopters which could maintain height when one engine cut, then they could almost bring the figure down to zero, but if they designed helicopters so that, when an engine cut, the pilot could not maintain height, then it was only fair to give him sufficient height range to get himself sorted out—and 300 feet was about that height range It might be that the civil helicopter would be able to hover with one engine out, but this cost pay-load, and they had to take a compromise between performance and what was feasible from the point of view of operating costs

Mr J A Preiss (*A & A E E , Boscombe Down*) congratulated the Author on his courage in tackling a problem which few would like to tackle, since the little that had been done in that field during recent years was only in the nature of preliminary investigations of the problem Furthermore, the Author was placed at a considerable disadvantage in his effort in that the experimental material available to him was limited to the B E A work of the last year or two

When the problem was considered from all possible angles of civil as well as military operations, a certain amount of confusion was most likely to arise Civil aviation problems had been commented upon by Mr MACINTOSH, and Wing Commander MITCHELL had dealt with the R A F requirements as regards the navigation of helicopters There were other very important requirements—those of the Navy The Navy were operating helicopters in greater numbers than anyone else in the country, but so far nothing had been heard during the discussion of their requirements

The Navy were obviously worried about the tactical limitations of operation of helicopters and by certain peculiarities in their navigation Their problem was to navigate a helicopter accurately over a relatively short distance of 60 to 100 miles without fixing or external monitoring facilities, relying entirely on flight instruments and pure Dead Reckoning

There was no question of carrying such aids as Gee or Decca There would be no worry at all if such facilities, or perhaps even better ones that were around the corner, could be used The helicopter was required to proceed from one unit of the fleet to another or from ship to shore in conditions of tactical radio silence, when all the radio aids were out of use and nobody was allowed to transmit

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Essential for the conduct of D R navigation of such flights were

Indication of aircraft's course
Measurement of airspeed (and time)
Knowledge of the wind velocity

It was necessary, therefore, to be able to measure, estimate or otherwise determine the wind vector It would appear that, for short ranges and at low altitudes, the various practical methods of wind velocity estimation well known to experienced Naval and Maritime navigators would be quite sufficient

It was further necessary to be able to measure the airspeed and here a certain amount of doubt existed as, according to Boscombe Down helicopter experts, the Position Error had been found to vary from aircraft to aircraft of the same type and with precisely the same installation Also, little was known so far about the measurement of low speeds below 25 knots, for which special instruments would be necessary Mr Preiss believed that one of the instrument firms was designing an airspeed indicator to cover the range from minus 20 to plus 20 knots

It was necessary, finally, to have a reliable and continuous indication of the course of the aircraft or, perhaps one should say, of the direction of its movement in still air, as no one seemed to be able to give a definition of the course of a helicopter !

Contrary to the Author's optimistic assessment of the behaviour of compasses in both S 51 and Bristol 171, it was a fact that neigher direct-reading nor remote-indicating gyro-magnetic compasses in the Dragonfly 3 behaved in anything like a consistent manner There were persistent discrepancies between ground and air calibrations of the compasses, proven beyond any doubt but so far unexplained, of such magnitude that D R navigation errors due to the direction factor alone would be of the order of 10 per cent Much effort was being devoted to this problem and, perhaps, the representatives of the Admiralty Compass Observatory present at the meeting would contribute some remarks on their findings in this field In all probability, one of the sources of trouble was the low frequency of the helicopter vibration which did not approach the frequency spectrums customary in fixed-wing aircraft

In D R navigation an accuracy of $\pm$ 5 per cent of the distance covered was not an unreasonable requirement If the case was considered of a helicopter which was to fly to a ship, say, 60 miles away when radio silence was enforced, an accuracy of $\pm$ 5 per cent meant that the sortie would be feasible only if the visibility was not worse than three miles Anyone with experience of Atlantic operations knew how seldom there was a visibility better than that

In conclusion, Mr Preiss did not contest that, given accurate measurement of course, airspeed and wind velocity, D R navigation of a helicopter could be conducted in the same way as that of a fixed-wing aircraft and with a comparable accuracy But he strongly emphasised that the measurement of direction at least was at present insufficiently accurate on Dragonfly 3 aircraft, while a lot remained to be discovered about the airspeed and practicability of wind velocity determination

It was, therefore, of particular interest to know how in the B E A investigation the yaw (or its absence) had been measured and how the compasses had been calibrated As regards yaw, it might be mentioned that there were strong, and theoretically not unfounded, suspicions at A & A E E that the yawing depended critically on the lateral C of G position, *i e* , on the state of loading of the helicopter

Mr Davies (*in reply*) said B E A had had satisfactory results with the E2A compass , the flights were completed with reasonable accuracy The compass problem which Mr PREISS had raised was a serious problem on which, lacking details, he could not offer other than general suggestions Indeed, as Mr PREISS said, the data on which Mr Davies had to work was pitifully small, and he was rather in a position of inviting expressions of points of view, not merely of inviting questions

The yaw meter was installed by the Bristol Aeroplane Company before the aeroplane was delivered—installed along the fore-and-aft axis of the aeroplane First of all, they estimated the order of the relation between differential pressure and yaw by extrapolation from results measured on another aircraft at Farnborough at a lower cruising speed Secondly, they determined it practically by flying along a straight railway line under conditions of low wind speed and using the drift sight to obtain information relating the fore-and-aft axis to the track Approximately 1 in water corresponded to 4 deg of yaw They were not greatly concerned with accuracy in that connection , they were dealing mainly with the null indication

As for compass calibration, they adopted normal methods The errors were quite small of the order of one degree and all the usual checks were made, doors open

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and shut, radio and electrics on and off, rotor stationary and rotating at flight r p m They did not go into the matter in great detail because they appeared to be getting reasonable results with the compass He could not give an offhand solution to the compass problems which Mr PREISS had raised, perhaps the trouble arose from vibrations and fuselage motions

Wing Commander Tonge (*Admiralty Compass Observatory*) said that after one year's work on the compass problem with the S51 type helicopter thay had arrived at the position which Boscombe had reached two-and-a-half years ago , he had been able to prove that what Boscombe found was correct In fact, they had had a little party on the previous day to congratulate themselves !

The problem was that compasses apparently would not work in the S51 type helicopter That was the Mark III type, which had the light alloy blades, non-magnetic He had been over every inch himself because he had felt that there must be some little man with parameters around the place ! Yesterday, to prove another point, they had been over the helicopter once more with a magnetometer—to prove to a sceptic that there was no vertical magnetism in the tail cone

When the job was first handed to them, they established contact with the manufacturers of the aircraft, who provided the vibration spectrum for 14 different posts in the aircraft Unfortunately, the best position from the vibration point of view was the worst from the magnetic point of view, being situated immediately beneath the engine The compromise position adopted was seven or eight feet aft of the engine, and about two or three feet along into the tail cone They were satisfied that that position was good from a magnetic point of view In that position, extensive tests—something like 30 hours of flying, with auto-observers, had been done They had worked with the Kollsman compass which they fitted in the aircraft because of the edge reading card There was a problem which might be partly vibration and might be partly magnetic in its build-up This had been resolved into a co-efficient C of some 6 deg , but it had been found that the gyro-magnetic compass of the G4 series showed a similar co-efficient C on the same sort of heading It was only co-efficient C as a systematic error, but on top of that there was a random error of the same order It was possible to calibrate the G4 and the Kollsman on the ground so as to get rid of all deviation On ground swings, with the engine running at normal revolutions, there was no deviation at all, but as soon as they were in the air the build-up to 6 deg co-efficient C was there and had become constant

Wing Commander Tonge said they had almost reached the end of their tether on this line of thought and now they were turning to the crystal ball or the man who sold compasses in Lisle Street to see whether they could put one of those in ! They were satisfied that there was a problem and that they could not say to the Admiralty, " These aircraft can be navigated within the limits " A complete change of thought was therefore about to be recommended, with some complete new line of investigation

Mr DAVIES had said that some people suggested that the trouble was due to induced magnetism through the movement of the rotor , this had been raised time and again and had been dropped time and again It was being taken up yet once more and the helicopter was to be put on a " prayer " mat—some means of stopping any leak-away of current, if there were a build up of current It had been worked out, however, that to create the sort of deviation which was troubling them the helicopter would need to produce something in the nature of 2 milli-volts at the rotor head, running away across the rotors, inducing a current of 4 amps through a resistance of 5 milliohms in the fuselage—and the experts with the slide rules had said that this just could not be

The possibility had not been dismissed , it was hoped to cut out the line of thought once and for all by simulating in-flight conditions and stopping a leak-away of current into the ground, if that were the cause Already they had worked on vibration and had every assistance from the firms interested, with offers of even more assistance A small light was fitted in the base of the detector unit, which was then photographed in flight so that they could watch the amount of movement of the detector element in its casing There had been many types of liquid damping experiment Such things as heavily damped silicone fluid had been used, but still there was an error, which did not alter very much By putting more liquid damping in the G4 type they had brought the null down from 10 deg to 1 deg and they had been able more accurately to read the residual co-efficient which still existed It would not be as bad if it were always 6 deg because then steps could be taken to offset it, but Boscombe were not looking forward to the procedure of having to calibrate the compasses in all

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helicopters for the Royal Navy—and that was what it might boil down to !

Wing Commander Tonge said his directors were very grateful for the opportunity of airing what to them was a difficult problem

Mr Macintosh said he gathered that the compass was calibrated in the usual way and that a corrector-magnet was used Was this problem possibly due to vibration not of the compass itself but of the corrector which had been put in, thereby affecting its influence ?

Wing Commander Tonge said the compass they had used was very good from the magnetic point of view The Kollsman compass had no correction in it at all Were it fitted it would be a straightforward needle magnetic correction The G4 used the electro-magnetic system, and called for a certain amount of deviation correction because it was in a different part of the aircraft In future tests it would be replaced in the tail cone

Dr G Hislop asked how many S51 aircraft had been checked for this apparently irregular behaviour of the compass

Wing Commander Tonge replied that Boscombe had used two over a period of two years, and one of the two had been handed to him The helicopter which was handed to them was the S51 Mark III and it was the only one which had been checked

Dr Hislop asked whether this behaviour had been observed in the Bristol 171

Mr Priess replied that it had been observed in Coastal Command

Wing Commander Tonge said that the S51 in which Mr DAVIES had done his tests was not the S51 Mark III , it was the S51 with the steel blades, not the light alloy blades, to the best of his knowledge

Mr J M Buckeridge (*M T C A*), who said he spoke as deputy for Mr Stallibrass, asked Mr DAVIES whether he had considered, or had any experience of during the trials, approach lighting, which was a possible assistance with equipment such as Decca, especially in built-up areas

Mr Davis (*in reply*) said that B E A had carried out some experiments with a simplified Calvert system The ground lighting consisted of an array in the form of a letter T, the shaft being 100 ft long and the bar 200 ft long This gave an indication of approach direction and horizon The flights, carried out mainly on nights of good visibility, gave very promising results On the other hand, when a natural horizon is visible, the pilot's problem is greatly simplified On one occasion after a series of tests on the lighted 'T' the pilot finally landed near the hangar with no aid other than his landing lamp ! Some landings were made in rather poor visibility and in general the array was considered to be a good one but further trials under more critical conditions were really required

Wing Commander F W Thompson (*R A F St Mawgan, Cornwall*) said that Mr DAVIES had mentioned topography and then dismissed it, whereas it might be a salient feature in D R navigation

In what area were the B E A tests carried out ? The Air-Sea Development Unit was in Cornwall, the land was by no means level and they had many local effects to overcome They had been carrying out a series of trials with the 171 instrumented in a similar manner to the B E A machine, with yaw meter or side slip indicator used purely as a flying instrument, not as a navigation instrument They had taken winds by using both Anson and Shackleton aircraft flying as near to the helicopter as possible, as well as by course flying with Met wind Visual checks had been carried out with 1 in and 2½ in to the mile maps for a track record, and it could not be claimed that they had achieved results as good as those of B E A That might be a reflection on the experience of pilots, but some were very experienced, and there was now a tendency to believe that in the appalling conditions caused by local wind effects the pilot tended to have a certain built-in yaw Wing Commander Thompson had decided to have a go himself , on inquiring whether there had been yaw, he was told " Yes,' but his staff had carefully not told him how much !

The change in local conditions might have a serious adverse effect

Referring to some trials carried out by the Navy, he said he understood that flying an S51 over land they came to conclusions similar to those of B E A The pilots bravely flew out to sea, flying a triangular course of about 60 to 100 miles total To their horror, they found—with the same pilot and aircraft—that in this case the errors

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were up to 12 or 20 miles, mainly lateral That was worrying, because some proposed helicopter tasks were well out to sea, operating completely on D R Another problem was that of going from dead stop to a forward-flying movement travelling some 3—4,000 yards and then back to dead stop again with an accuracy of yards

Mr Davies (*in reply*) said that the B E A flights were based at Gatwick and lay inside a region bounded by Lympne, Yeovil, Cardiff, Manchester, Birmingham and Peterborough They had covered representative country though much of it was fairly flat

He certainly did not want to give the impression of dismissing topographical effects—they were extremely important on a local basis On one occasion, flying from Manchester to Cardiff, they had been holding track perfectly but when the Welsh hills loomed up on the right they had drifted off and then back again This they attributed to wind change rather than to pilot error

Unfortunately it was virtually impossible to get a really accurate local wind and for that reason B E A had taken the easy way out by using a statistical allocation of errors which would at least give an idea of the order of errors that might reasonably be allocated to wind

It might be that B E A were lucky with their Bristol 171 from the point of view of yaw At cruising speed the rudder pedals could be released without any tendency to yaw developing and overall results confirmed this However, the tail rotor had to be carefully rigged to make this possible Perhaps the aircraft with which W/C THOMPSON was concerned were sufficiently different in layout not to have this facility

The fact that pilots achieved greater accuracy over land than at sea was perhaps linked with the high level of concentration needed for instrument flight in an S51 Over land the pilot had a number of visual external references to aid him but over sea he might have no more than a rather poor natural horizon This was the only suggestion he could offer It was supported by the fact that B E A pilots had completed blind flights cross country with reasonable accuracy, a very severe test Such flights, however, were extremely fatiguing

Dr M Morgan (*Marconi Research Dept*), referred to a statement in the Paper that on ascending the aircraft pitched downwards and on descending it pitched upwards What were the angles of pitch ? For a fixed-wing aircraft it was important to know the air speed to avoid stalling With a helicopter, was the air speed important for flying characteristics or for navigation ?

Mr Davies (*in reply*) said his figure for angle of pitch would have to be a guess Nose-up pitch varied with the conditions selected by the pilot but during normal descent it was about 5 degrees Nose down pitch was rather less, two or three degrees during climb but perhaps as much as 10 while accelerating rapidly

The important parameter to a helicopter pilot was rotor R P M rather than airspeed While the fixed wing pilot watches his airspeed, the helicopter pilot watches his R P M On the other hand, airspeed was not unimportant Referring to the relation between speed and power required for level flight—on the stable part of the curve airspeed was not critical but on the unstable side the pilot must know his approximate speed in order to be prepared for large changes in power required

From the point of view of navigation of course airspeed is equally important for fixed and rotating wing aircraft

Dr G Hislop (*Member—Fairey Aviation Co Ltd*) suggested that the 300 feet minimum height given in the Paper was too high, if they intended to be serious helicopter operators It was true that present design was such that one-engine-cut performance would not permit that height to be reduced, but the moral was clear design must be such that the aircraft could maintain height safely with one engine cut out As a consequence, the upper limit would come down, as come down it must

The Chairman, in closing the meeting, said the Paper had suggested what subsequent discussion had confirmed—that they were on the verge of discovering that ahead of them they had one of the biggest problems ever to face any branch of the helicopter art It was certain that for maritime operations something must be found very soon to solve the problems, for the helicopter promised to be a useful ASW weapon and the Navy would no doubt make the utmost use of it

He thanked the Author for the Paper and those who had contributed to the discussion for their excellent contributions

The proceedings then terminated

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