Navigation of Helicopters

By D M DAVIES, M A

A Meeting of the Association was held at The Royal Aeronautical Society, 4 Hamilton Place, London, W 1, on Friday, 9th April, 1954

In the Chair
NORMAN HILL, ESQ , A M I MECH E , A R Ae S

The Chairman, in introducing the Lecturer, said Mr DAVIES was a member of the Association and had been interesting himself for many years in operational, navigational and other problems associated with the helicopter He took first class honours in the Mechanical Sciences Tripos at Cambridge in 1942, and for four years afterwards was with the Ministry of Aircraft Production, mainly on project and performance analysis of high-speed aircraft

He left to join Mr N E Rowe in his research and special development department at British European Airways in 1946 Later he was in charge of a great deal of experimental work on the Clear Air Gust Project, and during this investigation he flew some 40 hours as navigator-observer on high-altitude flights in Mosquito and other aircraft

The helicopter attracted him in 1950 when he transferred to British European Airways helicopter unit and took on project analysis and experimental flight work on problems of civil helicopter operation, including the D R navigation of helicopters In 1953 he joined the Fairey Aviation Company as Senior Helicopter Project Engineer

MR D M DAVIES

Mr Chairman, Ladies and Gentlemen, May I say how honoured I feel at being asked to address this Association tonight I must confess at the same time that while writing this lecture I became aware that in an unguarded moment I had taken on a task of very considerable magnitude , the title " Navigation of Helicopters " ranges over so wide a field that it is frankly impossible to cover it adequately in a short lecture It has been necessary to impose restrictions therefore and I intend to consider only aspects of helicopter navigation which might be expected to throw up problems different from those already familiar in the fixed wing field These problems in general lie ahead , so far helicopter operations in this country have been on a small scale, using small aircraft, and the great majority of flights have been made in such a manner that sight of the ground is not lost other than momentarily We are, in fact, in the familiar position of having to generalise from insufficient data The performance and flying characteristics of the next generation of helicopters is uncertain , conflicting opinions have been expressed on how they are going to be operated, and while the enthusiasts visualise helicopters operating almost with the frequency of a London Transport bus service, others point to the capital expenditure needed to achieve this The subject is a difficult one but it will certainly be none the worse for being ventilated

STATEMENT OF PROBLEMS

The helicopter is essentially a short range vehicle for stage lengths up to about 250 miles It follows that many of the more advanced techniques such as astro navigation, pressure pattern flying, and so on, are of no practical importance here Probably the main problems of short range navigation are the selection and use of radio aids and Air Traffic Control Since helicopter operations will be different in some respects from short range operations of fixed wing aircraft, it is necessary to consider whether these differences are such as to justify separate radio aids

Another group of problems results from the special flying characteristics of the helicopter It derives its lift and propulsive force in a novel way and by the use of lateral cyclic pitch control the pilot can readily produce a force in the direction of sideslip This raises the suspicion that yaw may be applied inadvertently at cruise speed Again the stability of present day helicopters leaves much to be desired and for this and other reasons accurate flight under visual conditions is more tiring than on most fixed wing aircraft Blind helicopter flight is being conducted on an experimental basis and much remains to be learnt about this Finally, the vibration spectrum of a helicopter can produce peculiar instrument behaviour and it is sometimes suggested that induced magnetic effects from the rotor affect the compasses adversely

There are, therefore, three main headings to which problems of navigation associated purely with helicopters can be assigned

(*a*) Radio or other navigational aids needed

(*b*) Air Traffic Control

(*c*) What may be termed D R Navigation

D R NAVIGATION

It is convenient to consider first those items which have been grouped together under the heading D R Navigation Now it may seem rather elementary to talk about D R Navigation, but properly considered, D R is the basis of all navigation and is fundamental rather than elementary In fact it is so fundamental that it is a little difficult to find out just what it means ! In default of a formal definition it is taken here to be that process by which a navigator takes the courses and airspeeds flown by the pilot and plots them to give an air position He then applies a correction for mean wind velocity to give a D R position which should ideally correspond with the actual position The uncertainties arise from errors in holding course and airspeed which are associated with the aircraft itself—or more correctly the aircraft/pilot combination, and from errors in mean wind velocity which are not necessarily associated with aircraft behaviour

A rather brief investigation of the D R Navigation of helicopters was conducted recently by British European Airways with the support of the Ministry of Supply and the Ministry of Transport and Civil Aviation I am indebted to these agencies for permission to refer to the results obtained These are discussed in the following paragraphs, firstly individual sources of error and finally the overall accuracy likely to be obtained

Yaw A Bristol 171 was fitted with a yawmater and tests carried out to see whether pilots are liable to fly inadvertently with yaw It was found that above about 70 knots cruise speed starting from an untrimmed state pilots could settle down to level flight with effectively zero yaw without reference to the yawmeter The yawmeter was available here to the observer only At a cruise speed of about 80 knots the tail rotor pedals could be released without effect On no occasion did the yaw exceed ± 1° other than momentarily

Yaw was next deliberately applied while flying straight and level at 80 knots At ± 4° of yaw marked stick and rudder forces were required and the aircraft banked perceptibly At ± 6° of yaw the bank became pronounced and the speed fell off markedly

No yawmeter was fitted to the S51 aircraft available but the general results of cross country flights and compass checks along long straight railway lines were that yaw, if present, was small

No tendency was found on the Bristol 171 for yaw to increase when flying with a high cross wind component even up to 15° of drift This is not surprising in view of the stick forces necessary to produce yaw

It must be remembered that the cyclic pitch control of the Bristol 171 is reversible , large helicopters of the future are likely to have power operated controls giving no " feel " In this case the pilot must rely on his artificial horizon which should show no bank when flying straight and level One would consider it unlikely that liability to yaw will present a problem at cruise speed, the flight condition important for navigation, particularly as future designs will probably have more directional stability

Compasses The magnetic compass of the Sikorsky S51—a Kollsman type, has always given satisfactory service, apart from the fact that it is difficult to hold a course on the magnetic compass in rough air because the compass card becomes unsteady The magnetic compass is used rather as a means of correcting the directional gyro periodically , holding courses on the directional gyro presents no great difficulty

The original magnetic compass of the Bristol 171 was a P 12 type The particular installation tested was found to give large errors—15 to 20° in flight—even though a ground swing showed small errors This was eventually traced to faulty suspension springs On the ground the compass behaved normally but in flight aircraft vibrations caused the card to rotate through 15—20° and remain so rotated—a very peculiar effect The P 12 was replaced by an E2A compass which has given satisfactory service , again this is used as a monitor for the directional gyro

Airspeed No direct checks of the A S I installation were made but A & A E E have calibrated both the S51 and the Bristol 171 with an air log Errors are small at cruise speed and seem to be consistent, though appreciable differences occur between level flight, climb and power-off descent

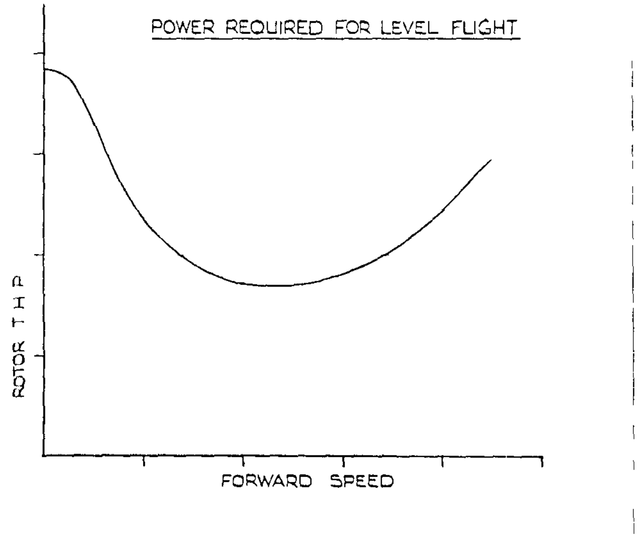
Vibration There is one important feature of helicopters which affects instrument life and sometimes behaviour while in service This is the vibration spectrum to which rotating wing aircraft are subject Large amplitude, low frequency vibrations associated with the main rotor are present and special protection is sometimes needed Anti-vibration mounts of the normal fixed-wing type are usually unsuitable because of resonance difficulties This is not strictly a navigational matter but it does need stressing, and unserviceable instruments certainly affect navigation

General Flight Behaviour It is generally accepted that helicopters are more difficult to fly than comparable fixed wing aircraft This means that to achieve a given standard of accuracy of instrument flight a helicopter pilot must keep up a higher level of concentration, alternatively if he cannot keep up this higher level his accuracy will suffer The important question is whether this state of affairs is likely to persist Now the main difficulty in flying a helicopter at cruising speed is probably the instability of current types It was demonstrated in America however, on the Sikorsky S51, that the incorporation of horizontal tail surfaces has a very beneficial effect (Ref 1) Flying characteristics can also be improved very greatly by use of an automatic pilot or some type of automatic stabilisation There is good reason in fact to expect that future helicopters can be made acceptably stable at cruising speed If this is the case then pilots should be able to fly blind with a facility approaching that accepted on fixed wing aircraft Present indications are that this will be done on a normal blind flying panel or at least one incorporating only minor modifications

This does not imply that a complete solution of blind flying problems is in sight throughout the speed range There are at least three factors, apart from instability, which make blind flight difficult at low speed more specifically below the minimum power speed The most important is that between about 5 knots and 35 knots, on existing small designs, the power required for level flight falls very quickly (Fig 1) The speed range may change somewhat on future designs but the rapid change of power appears to be inescapable This means that a pilot flying in this range may be faced with having to make major corrections to engine power for a small speed change, to maintain steady flight, apart from controlling the attitude of the aircraft The problem arises acutely in steep descents at low forward speed and explains partly why such manoeuvres are unpopular with pilots The second factor is that fuselage attitude—and correspondingly the indication of the artificial horizon—changes, under varying flight conditions, in a manner likely to bewilder a pilot trained on fixed-wing aircraft Thus during descent the Bristol 171 adopts a nose up attitude and if the descent is broken off and the aircraft climbed away (a sort of overshoot) the fuselage is nose down, particularly during accelerated flight The pilot in fact has to learn all over again what the pitch indications of the artificial horizon mean

The third factor is the need to maintain rotor r p m and hence lift, by manual control of collective pitch—a demand on the pilot which is peculiar to helicopters In steady flight only minor co-ordinations of throttle and collective pitch are required, but when changing the flight regime, as from level flight to descent, the co-ordination may occur much of the pilots' attention The collective pitch lever is then a major flying control and rotor r p m a vital instrument The provision of automatic pitch control has of course been suggested, but as far as I know, no-one has yet put the suggestion into practice

FIG 1


POWER REQUIRED FOR LEVEL FLIGHT

Overall Accuracy The general conclusion from this examination is that there is no reason to expect large errors in the D R Navigation of helicopters , errors, that is to say, large compared with those found on fixed wing types operating in similar conditions at the same cruising speed In order to confirm this a series of cross country flights were made over distances up to 100 miles on the Bristol 171 and the Sikorsky S51 Flights were VFR contact at 1,000 ft but the pilot flew courses and airspeeds given by the navigator and made no attempt to check his position en route The flight plan was drawn up initially on forecast winds, then during the course of the flight a revised wind was estimated from successive ground positions and used to compute a revised course and E T A The opinion of all pilots concerned was that the en route corrections were of normal magnitude and that the selected courses and speeds could be held satisfactorily

This was encouraging but it was clearly desirable to obtain quantitative data so that standards of accuracy of helicopter and fixed-wing types could be compared The first difficulty is to find what is acceptable on fixed-wing aircraft where D R has been taken for granted for many years and errors are generally considered to depend mainly on the navigators skill A statement is made in Ref 2 that the 50% error may be taken as 2° of track in conjunction with 2 minutes per hour flown This is a vector error of about 6% of distance flown and is intended to give only a general guide to what order of error is acceptable The next problem was how to plan the helicopter flights to give quantitative information

The main task is clearly to separate wind errors from other D R errors but this is extremely difficult to do All methods of measuring wind are subject to error , this may sound like a platitude but the errors are usually rather large The helicopter itself could not be used for wind finding because such a process would include at least some helicopter errors Meteorological forecasts based on synoptic charts are somewhat unreliable at 1,000 ft where topographical effects are important Balloon ascents take no account of the variation of pressure gradient with distance and little account of the inherent variability of wind with time Finally, it was decided to use forecast winds only and to allocate errors on a statistical basis A flight plan was drawn up on forecast winds and the pilot flew strictly to this flight plan until at E T A actual position could be compared with D R position

In the event only a few flights were completed successfully The availability of the aircraft was limited by other demands and a number of flights had to be discontinued because of low cloud, poor visibility, air traffic control requirements and so on The results are not sufficient for statistical analysis therefore but they are at least of interest in indicating the order of accuracy achieved Table 1 shows typical results , the vector errors vary from 2% to 13% of distance flown and a rough estimate of the 50% error gives 7% of distance flown

TABLE 1

D R FLIGHTS USING FORECAST WINDS

Aircraft	*Distance*	*Forecast Wind*	*Vector Error*	*Remarks*
S51	40 n miles	260°/10 kts	3%	V F R
S51	44 „	080°/15 „	10%	Simulated blind
S51	47 „	080°/15 „	13%	Simulated blind
S51	92 „	300°/ 5 „	2%	Simulated blind
171	98 „	140°/10 „	5%	V F R
171	111 „	170°/10 „	11%	V F R

This compares not unfavourably with the fixed wing standard It should be noted that three of the flights shown in Table 1 were made entirely on instruments, the pilot flying under " two stage amber " This simulated blind flight demanded greater concentration from the pilot but had no obvious effect on the accuracy with which courses and speeds could be held

Since, as already stated, the flights completed successfully were few in number, the statistical allocation of wind errors cannot be made The likely order of these errors however is of interest The Meteorological Office have given what might be termed an unofficial estimate that the 50% error of the forecast winds used in this experiment is likely to be at least 5 knots vector error For a cruise speed of 80 knots this means that the wind error alone is about $\frac{5 \times 100}{80} = 6\%$ of distance flown on 50% of occasions It would appear probable that, as might be expected at low cruising speeds, wind errors play a large part in determining overall errors

In the course of the trials a Drift Recorder Mk II was installed in the Bristol 171 for assessment At 1,000 ft the field of view is narrow, making the recorder facility virtually useless, but by following a series of objects across the sighting lines it was found possible to take a good mean drift even in rough air and, rather surprisingly, track was held within 2° on each test flight On the other hand it does require a minute or so to take a mean drift and of course ground speed errors remain unless the flight is interrupted periodically to take three drift winds

Extrapolation of Errors The discussion of D R errors at the 50% level is interesting for comparative purposes but it is desirable also to give information on what the errors are likely to be at, say, the 95% level The experimental data are insufficient for this to be done other than on a theoretical basis and to do this assumptions must be made about the form of the distribution

The difference between D R position and actual position results from errors in track and ground speed—giving two components effectively at right angles The basis assumption is that the vector error from each source is subject to a normal distribution having the same standard deviation This assumption was put forward by Mr Manning, lately of B E A , and a similar approach has been used by the Meteorological Office in the treatment of wind forecasts (Ref 3) If each source of error can be expressed by a normal distribution

$$f(x) = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-x^2/2\sigma^2}$$

where σ is the standard deviation, then the combined errors give a vector distribution of the form

$$f(r) = \frac{r}{\sigma^2} e^{-r^2/2\sigma^2}$$

The resulting curve is shown in Fig 2 and clearly the errors are equally likely to occur in any direction If for example the 50% error is 7% of distance flown, then after a 100 mile flight, the actual position will be within a 7 mile radius of the destination on 50% of occasions Extrapolation to lower probability levels can be done from Table II which is derived from equation (2)

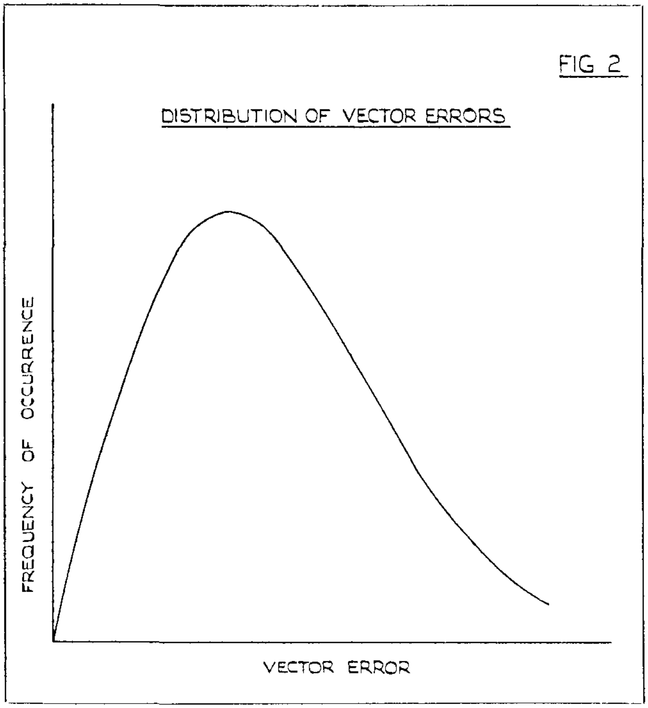


FIG 2

DISTRIBUTION OF VECTOR ERRORS

TABLE II VECTOR ERROR DISTRIBUTION

Proportion of occasions	50%	75%	85%	95%
Radius/standard vector deviation	0 83	1 18	1 38	1 73

So that if the 50% error is 7% of distance flown, the 95% error is 15% of distance flown Put in another way, on 95% of occasions after a 100 mile flight, the actual position will be within 15 miles of the desired destination

Since the basic figure of 7% was based on very limited data, these figures should be taken as illustrative rather than exact They do show, however, that large errors can occur not infrequently unless corrections are fed in the course of the flight Radio aids which make this possible are discussed in the following paragraphs

NAVIGATION AIDS

While D R can be discussed independently of the operational role envisaged, radio aids must be associated with the purpose for which the helicopter is going to be used The Services have their own problems which only they are competent to discuss and I intend to limit consideration to the civil transport helicopter

First of all, it is pertinent to ask whether radio aids are in fact necessary R W Usher in his lecture on helicopter navigation in 1948 (Ref 4) took the view that acceptable regularity could be obtained flying " V F R Contact " The restrictive conditions however were that flights were considered in daylight only and that visibilities down to 550 yds were thought adequate I do not think that operating companies would be very happy about being limited to daylight operations, nor would the pilot be very happy flying larger faster aircraft in 550 yrds visibility It is accepted nowadays I think that ability to fly blind and at night is essential for air transport operations Nevertheless the suggestion that this is not necessarily so is a salutary reminder that facilities are determined very largely by traffic density In very low traffic where regularity and punctuality are relatively unimportant no aid is necessary As an intermediate stage VHF/DF is probably adequate, while in the crowded airspace of the United Kingdom where operators work to tight schedules comprehensive radio aids are required The problems of the navigator then fall into two parts

(*a*) En route (*b*) Landing and take off

En Route When en route the radio aid should enable the crew to proceed to within close proximity of their destination and enable their position at any time to be determined with sufficient accuracy to forecast time of arrival, to avoid high ground, and for purposes of air traffic control All of these requirements are of course common to helicopters and fixed wing aircraft, and therefore one turns to the fixed wing field for guidance

It would seem, however, that the implementation of international standards is still somewhat obscure B E A is at present using a system of M F beacons in conjunction with a radio compass, together with V H F / D F For future use, the Corporation has expressed interest in the Decca Navigator plus Flight Log but is also keeping an eye on V H F Omni-Range plus Distance Measuring Equipment A choice has yet to be made in fact between the type of aid which provides a fix and the type which provides a radio range The probable trend of future helicopter operations however does, I think, make the corresponding choice rather easier to make The pattern of operations was discussed at the recent I A T A Helicopter Symposium and the proceedings described in an excellent report (Ref 5) The relevant points are as follows

(*a*) Operations will be intercity—up to about 250 miles— and metropolitan (down to a few miles)
(*b*) Operations will be both into fixed-wing airfields and into special small sites
(*c*) Cruising altitudes will vary between 7,000 ft and about 500 ft The favoured height band is likely to be 1,000 ft —3,000 ft
(*d*) The cruising speed will be in the region of 130 knots

It would appear that instead of serving a relatively small number of fixed wing airfields associated with large towns the helicopter will wish to serve a much larger number of sites It would be difficult to lay out radio ranges to serve such a complicated network properly and this favours the " fixing " type of aid which inherently has more flexibility

The second point that emerges is that the helicopter wishes to fly at low altitudes , this favours an aid which does not use high radio frequencies Now the radio aids available are as follows

1 M F beacons, the aircraft carrying a radio compass
2 V H F Omni-range

3 G E E
4 Decca Navigator

The only fixing aid which does not use high radio frequencies is the Decca Navigator and attention is therefore directed to this This is no original conclusion and B E A have been for some time carrying out an assessment of the Decca Navigator in conjunction with the Flight Log—a device which automatically plots the location of the aircraft on a map The use of the Flight Log as a navigational aid for helicopters together with other operational problems was discussed by Mr R H Whitby in Ref 7 Since I am no longer with B E A I cannot report the results of the experiments, though I understand they are very promising No doubt a number of problems remain to be solved but fundamentally the line of development does seem to be the right one

Take-off and Landing If the landing or take-off is made in a region which has no fixed-wing airfield—in particular a region not in a control zone, the problem is somewhat simplified The pilot can approach to within close proximity of his landing site on the navigational aid, assumed to be the Decca Flight Log Under V F R the final landing is then visual but in I F R the pilot must first break cloud He may possibly be heading for a landing site 300 ft in diameter with a cloud base about 300 ft above ground, and I do not think he will be able to do this on the Flight Log On the existing device the presentation may, depending on the locality, correspond to a map scale of two miles or more to the inch and even if wider scales were made available the pilot would find difficulty in controlling the aircraft while at the same time monitoring his ground position in conjunction with altitude After all, he must descend through cloud probably at a fairly steep angle, and he is entitled to demand a guarantee that when he breaks cloud he will be correctly lined up for final descent and landing This becomes increasingly necessary as limits of cloud base and visibility are lowered With all engines operating it would be possible to make horizontal corrections or even to climb away again, though it is not desirable to have to do this If an engine should fail during the final phase the performance margins are likely to be extremely critical—to say the least of it

This indicates the need for a landing aid Such a provision of course entails extra expense and in the practical case this must be weighed against the benefits derived It is not possible to give general requirements but it seems likely that in important centres with low limiting cloud base a landing aid will be required It could be of the I L S type or some modification of G C A The G C A type would have the advantage of greater flexibility but the disadvantage of requiring an operator Whatever the aid the main difficulty is that of flying the aircraft blind at slow speed Stability may be provided by automatic devices, but large power variations with speed (at low speed) will remain as a fundamental characteristic If then the aircraft is descending in a region where a large wind gradient exists, the pilot may have to contend with large changes of power required and hence rate of descent The vertical speed indicator usually provided is subject to lag and some means of overcoming this is most desirable The altimeter is also subject to lag and it may eventually prove necessary to use a radio altimeter for this phase which also gives rate of descent as a differential

AIR TRAFFIC CONTROL

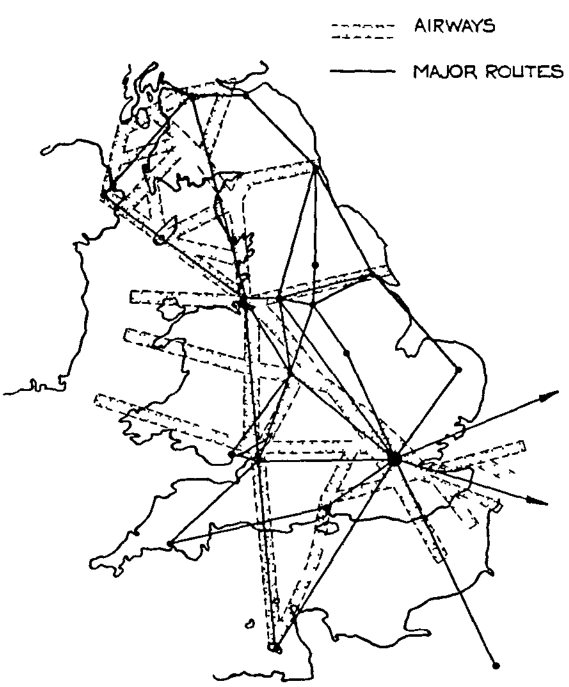
The problem of Air Traffic Control is one which I approach with some diffidence, it is really a matter for the specialist but one which cannot be ignored in a consideration of helicopter navigation Control of high density civil air traffic is a complex business and in the U K the sometimes conflicting demands of the civil and military authorities on the limited airspace available make the problem doubly difficult Again, two main facets arise

(*a*) En route control

(*b*) Entry into and departure from control zones

En route control For control of fixed wing traffic in I F R an Airway system has been developed which is available only to civil traffic—or more generally to aircraft under M C A control The Airways extend from 11,000 ft down to about 3,000 ft and may be taken as having a lateral extent of about 10 miles Outside these lanes military aircraft operate under separate control and cross the airways only under conditions which ensure safety—usually either radar surveillance or by arrangement with M C A Control

HELICOPTER ROUTE NETWORK FIG 3



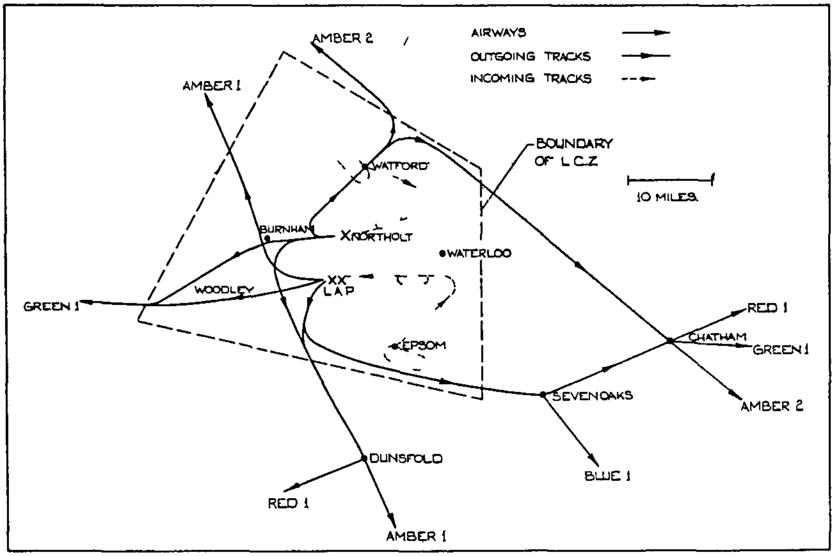
It is important to stress that the Airway system was developed as an essential safety requirement Civil aircraft would wish complete freedom to fly anywhere but the danger of collision in cloud must be guarded against

Fig 3 shows the tentative route network proposed by Mr Masefield in his lecture to the Helicopter Assn (Ref 6) with the airways overlaid Clearly many of the routes could fit in to an airway system and the trunk routes are already so covered Future development of the route network however is likely to make it more extensive and complicated, with consequent difficulty in conforming to an airway system It is difficult to avoid the conclusion that large transport helicopters should use airways in I F R if possible The prospect of fast jet aircraft and helicopters flying in the same airspace but under separate control is hardly acceptable But this does limit rather severely the flexibility which should be the keynote of helicopter operations The allocation of a height band between say 1,000 ft and 3,000 ft over large areas of the country would solve the problem, but one feels that such a demand for airspace is likely to meet powerful opposition

Metropolitan operations, that is, flights over short stages in densely populated regions, will probably require an allocation of airspace on a purely local basis This should present no great difficulty unless the region is a Control Zone This point is discussed in the following paragraphs

Control Zones If the landing area is near or on a fixed-wing airfield, in particular in a control zone, then the problem of the relation between helicopters and fixed wing traffic really comes to a head En route they have been rather uneasystable mates—while the helicopter tends to make a nuisance of itself by flying rather slowly, it also minimises interference by

LONDON CONTROL ZONE (ILLUSTRATIVE) FIG 4



NOTE INCOMING AIRCRAFT ARRIVE AT EPSOM & WATFORD ABOVE 5000 flying at lower altitudes In control zones however all aircraft fly low and the complexity of the problem may be illustrated by consideration of the London Control Zone Fig 4 shows an illustrative presentation of the L C Z giving probable incoming and outgoing tracks for Northolt and London Airport in a westerly wind In the critical case when Instrument Flight Rules apply, incoming aircraft enter the zone from an airway and proceed to Epsom or Watford above 4—5,000 ft The let down to ground level is then as shown Outgoing aircraft follows the routes indicated, climbing to about 4,000 ft as they enter the airways Inside the Zone itself only one or two tracks intersect and incoming and outgoing traffic are given height separation More generally the procedures must allow for Bovingdon traffic, for the occasional overshoot or radio failure, and for other wind directions, and the techniques are complex and highly integrated When civil transport helicopters arrive on the scene they will complicate matters still further by wanting freedom to land not only at Northolt and London Airport but also at a site near the centre of London—say Waterloo

It is pertinent at this stage to consider the slow speed characteristics of civil transport helicopters It is probable that the minimum power speed will rise from about 40 knots to 80—100 knots and in order to hover at maximum weight, high percentage power will be required—with correspondingly high fuel consumption Remembering that it is likely to be rather difficult to hover a helicopter blind it becomes evident that a pilot will be reluctant to fly at zero speed unless it is absolutely essential In Control Zones he would prefer not to cruise appreciably below his minimum power speed This indicates that control techniques should not be based on the assumption that the helicopter can be told to hover over a pin point but on the assumption of a cruising speed of the order of 80—100 knots In this case the helicopter is hardly distinguishable from a fixed wing aircraft until it enters the landing phase A helicopter is, of course, able to fly at slow speeds down to zero speed but I do not think that control techniques should make it necessary to do so other than in emergency

B E A have operated helicopters into the London Control Zone for some time using S51 and Bristol 171 aircraft flying V F R at heights between 500 ft and 1,500 ft The general principle was to give the helicopter special entry points and holding points, finally entering L A P at right angles to the duty runway If the helicopter track intersected a fixed wing track, the helicopter was expected to hold over a small area until the way ahead was clear This is the one way of entering the Zone, but every intersection presents a timing problem to the Controllers and the pilot is likely to be faced with a good deal of low speed flying—an unpopular flight regime It puts the helicopter in fact in a subordinate position compelled to enter, as it were, against a series of traffic lights

An alternative is clearly that helicopters enter from the Airways as do fixed wing aircraft Entering aircraft have height separation from outgoing and the helicopter adheres to the fixed wing pattern until it finally breaks away towards its separate landing site This would seem to be the better alternative since Controllers would be spared the difficulty of dealing with multiple track intersections

The problem of outgoing helicopters remains , high density operations from the hypothetical Waterloo site in addition to Northolt and L A P would call for extremely careful co-ordination The transfer of Northolt 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