ALL WEATHER OPERATION OF HELICOPTERS

Part I—Engineering Aspects

By P A HEARNE, D L C, D C Ae, GRAD R Ae S

Part II—Piloting Aspects

By J W REID, D F C

Papers presented to The Helicopter Association of Great Britain in the Library of The Royal Aeronautical Society, 4 Hamilton Place, London, W 1, at 6 p m on Friday, 8th March, 1957

WING-COMMANDER R A C BRIE (*Vice-President*) in the Chair

The CHAIRMAN, in opening the meeting, said it was a matter of major importance to all concerned not only to have suitable helicopters to use, but also to ensure that when the operators got them they were capable of being used in such a way as to make nonsense of the frequently heard comment that there was no economic future in scheduled operations It was, of course, a fact that unless helicopters could be operated round the clock, in foul weather as well as fair, by night as well as day, like normal means of transport, then they would not take their rightful place in the general transportation set-up

The problems involved were, however, well appreciated and for many years a considerable amount of research and development work had been carried out by B E A 's Helicopter Experimental Unit under the sponsorship of the M T C A with the object of having such problems resolved by the time that multi-engined helicopter transports became available The many aspects involved would be dealt with fully by the two Authors

In introducing the Authors, the CHAIRMAN said that from 1943 to 1946 Mr HEARNE had studied aeronautical engineering at Loughborough College and from 1946 to 1947 he was an aerodynamicist with Saunders-Roe In the two years from 1947 to 1949 he was at the College of Aeronautics, Cranfield, where he took a postgraduate course in aeronautics From 1949 to 1954 he was a technical officer with B O A C in the Project and Development Unit Since 1954 his activities had been as a helicopter project engineer with B E A As such he was responsible for the planning and execution of experimental flying programmes Last year he had spent a few months in America with a Research Scholarship at the Massachusetts Institute of Technology working on helicopter stability problems He was a pilot, unfortunately not yet on helicopters, but he had a Flying Instructor's endorsement and was a member of the Council of the Royal Aeronautical Society

First Officer REID was a pilot who had spent the past three years with the B E A Helicopter Experimental Unit Prior to that he had been an airline pilot, and thus has an appreciable background of flying experience Born in New Zealand, and educated at Christ's College, Christchurch, and New Zealand University, he learned to fly and obtained his 'A' licence in 1938 From 1940 to 1945 he served in the Fleet Air Arm, Royal Air Force and Royal New Zealand Air Force From 1945 to 1949 he was chief flying instructor at the Nelson Aero Club, New Zealand At the end of 1949 he formed Northwest Airlines and as chief pilot operated scheduled services with Dove and Gemini aircraft from 1950 to 1952

He joined B E A in 1952 and had flown 1,400 hours on helicopters , his total flying time being 7,100 hours His first experience with helicopters was in 1947, when the Byrd Antarctic Expedition, which was equipped with one or two Sikorsky R-5's, happened to use Wellington, New Zealand, as a base It was then that he had his first passenger flight, and it was not surprising that the memory had lingered

All Weather Operation of Helicopters

PART I Engineering Aspects

By P A HEARNE,
D L C , D C Ae , GRAD R Ae S

The operation of helicopters in all weathers is an essential future development if we are to reap the full benefits of a vertical take off aircraft Civil operators hope to use helicopters on short international routes such as London-Paris, as domestic inter-city transports, say between London-Birmingham-Manchester, and in certain circumstances as inter-aerodrome or city to aerodrome services, such as those of Sabena and New York Airways All these types of operations will demand a regularity at least as high as fixed wing aircraft and in the inter-city role a regularity approaching surface transport In turn, this indicates that helicopters must operate in weather minima at least as low as the current fixed wing limits of 400 yards visibility and 300 ft cloudbase, and should preferably approach the limits of surface transport which continues to operate after its own peculiar fashion, down to visibilities of the order of 10 to 20 yards

The helicopter with its slow approach speed and excellent manoeuvrability is well suited to this type of operation Present knowledge suggests that it should be readily possible to conduct operations down to 200 yards visibility and 200 ft cloudbase, provided the necessary aids are made available As experience is gained, it is most likely that these limits could be reduced to 150 yards and 150 feet However, as the helicopter pilot, like his fixed wing colleague, must have adequate time for transition to visual guidance before landing, it does not seem likely that these limits could be much reduced before the development and acceptance by civil operators of either completely automatic landing or some radical new landing aid

Tonight I would like to give you a brief summary of the technical side of some of the work which the Helicopter Experimental Unit of the Engineering Department of British European Airways has been doing towards the first aim of operations in 150 yards 150 feet conditions The future developments necessary to achieve zero zero operation are both shrouded in secrecy and clouded in confusion, with I suspect, a higher proportion of the latter I will, therefore steer clear of them in discussing the technical aspects of the subject I would however mention that the development of entirely new concepts of instrument displays as in the IM HEP project of Bell Aircraft and the production, and use by civil operators of a fail safe landing coupler are the type of work which must be undertaken before zero zero operation can be realised

1 AIRCRAFT CHARACTERISTICS

The prime requirement for all future civil operations and particularly all weather operations, is a multi-engine helicopter with adequate performance following failure of one engine The consequences of engine failure in a single engine helicopter followed by a rapid descent whilst above a low cloud base are a completely unacceptable risk to the civil operator and licensing authorities British and American multi engine helicopters of this type might be available in 1960 The first generation of these aircraft will weigh upwards of 15,000 lb and will carry some 18-25 passengers An experimental prototype which should have reached this stage of development is the Bristol 173 which is 51 ft long with two four bladed rotors of 49 ft diameter which are interconnected by a synchronising shaft As the Bristol 192C, which should be the first civil derivative, it would be powered by two Napier Gazelle free turbine engines and would carry 17 passengers over 160 miles at a speed of 120 knots

The second generation of helicopters now under development are typified by the Fairey Rotodyne and Westland Westminster, both of which are turbine powered and should carry upwards of 40 people at a cruising speed of 150 knots over a 200 mile range

Perhaps the most important single development in helicopter design still outstanding is the development of ice protection equipment For reasons of Air Traffic Control, among others, helicopters will often be forced to fly in icing conditions for appreciable lengths of time

Rotor icing when it occurs seriously reduces the lift drag value of the rotor blades Since helicopters have so far carried out relatively little cloud flying, icing incidents have been fairly rare However, during the Dutch Flood rescue operations in 1953, two B E A S 51's encountered severe icing and were forced down within two minutes of entering icing conditions It was not even possible to hover before landing and the aircraft could only be flown onto the ground in a controlled descent condition

Current research into anti-icing systems includes electric mat, liquid and hot gas methods It is impossible at this stage to say which will be the most effective What can be said is that de-icing is a *must* for civil all weather operations

Design refinements are also necessary to make helicopters suitable for operations in high wind conditions The limitations of the low cruising speed of current aircraft will happily be removed in the next generation Passengers, I hope, will not suffer the indignity, as I did recently, of being passed by one of British Railways few fast trains More important, since it affects the safety of the aircraft is the ability to start and stop the rotor in strong and gusty winds Unless suitable restrainers are built into the rotor system, the blade motion can be completely uncontrollable whilst starting or stopping in these conditions and a blade can strike the aircraft and severely damage it Current aircraft have rotor starting limitations of 30-40 knots and this must be increased to 50-55 knots for future aircraft

Amongst the myriad of other design requirements for an all weather helicopter, I could perhaps mention the need for a very good view from the cockpit at all times, particularly during the approach phase The problems of providing sufficient transparent area to give this view over the wide range of aircraft attitude coupled with the need for rain wiping, demisting and defrosting of this area are by no means negligible and are but one of a number of difficult design problems of this type of helicopter

2 INSTRUMENT FLYING CHARACTERISTICS

To operate any type of helicopter in all weather conditions, it is necessary to have good instrument flying characteristics, a term which is synonymous with good aircraft stability

Unfortunately, the fully articulated rotor is very unstable with changes of angle of attack which means that slight disturbances, if left uncorrected, rapidly result in violent divergences from the steady flight path

Some improvement can be gained from aerodynamic means such as tailplanes, fins, etc , and it is true to say that in this country such remedies have not been fully explored However, these measures can only be palliatives and cannot solve the major problem of rotor instability

In recent years B E A has flown many hours actual and simulated instrument flying in the Bristol 171 helicopter The instruments used are fairly standard , the turn and slip is omitted but a slip bubble is fitted above the horizon , the rotor and engine r p m indicator which is a major instrument in helicopter flying forms part of the primary display The Decca Flight Log, Decometers and Lane Identification meter are mounted on the right hand side of the cockpit

The cockpit of the S 55 (Fig 1) is arranged for right hand captaincy and the instrument layout is a mirror image of that in the Bristol 171 Whether this is the correct layout or not we hope to determine shortly by photographing pilot eye movements in instrument flight

From our instrument flying trials two principal limitations became apparent

(1) The inability of the pilot to control the helicopter on instruments below 40 knots , and

(2) The impossibility of maintaining adequate control in turbulent conditions for any appreciable period of time

In addition, there is the overall problem of pilot fatigue caused by the large mental effort required to fly an unstable aircraft on instruments Fixed wing pilots who complain about the poor instrument flying qualities of conventional aircraft really " ain't seen nothin' yet "

The lack of control below 40 knots results from the loss of the aerodynamic contribution of the fuselage to directional stability at low speeds The pilot has to concentrate so hard to maintain direction that he can no longer monitor the other flight instruments satisfactorily and it becomes impossible to maintain accurate control about all three axes

In turbulent conditions the limiting factor appears to be pilot fatigue The behaviour of the unstable helicopter in turbulent air demands so many corrective control movements simultaneously that the pilot cannot absorb all the information from the instruments and translate it into control movements Co-ordination between the pilot's visual interpretation of the instruments and his muscular control movements disappear and he can no longer maintain complete control of the aircraft

The solution to these two problems and the overall problem of providing good instrument-flying characteristics is the fitment of a device which provides artificial stability and can also be made to function as an automatic pilot The British development in this field, carried out jointly by R A E and Louis Newmark, Ltd , was described fully in a recent lecture to this Association

Fig 1

Briefly, it consists of stabilization signals injected into the control system from simple electrical rate gyro and amplifier circuits The pilot flies the aircraft through the rate gyros by displacing their datums by means of electrical signals from his cyclic stick, that is to say the normal control column By adding some simple pick offs to the flight instruments, the installation functions as an autopilot

When artificial stabilization is applied to a helicopter it then behaves in normal level flight as a very stable fixed-wing aircraft, though if the pilot makes a manoeuvre the manoeuvrability of the helicopter is not reduced by the high degree of stability about the datum condition

Flight tests of this system have shown very marked improvements in the flying characteristics of the S 55 to which it is fitted It is certain that all future civil transport helicopters will fit some sort of system of this kind

As regular scheduled instrument flying will be dependent on autostabilization, it will be necessary to guard against its failure This is best done by improving, so far as possible, the unstabilized flying qualities of the helicopter This in itself, will probably permit instrument flight over a limited flight regime and further safeguard could be a flight director system This is an instrument system in which the pilot is presented visually with the signals or directions concerning the magnitude of the control corrections to be made which he then makes by his human muscles, roughly corresponding to the electrical signals which would be fed to the control servos from an autopilot Flight trials in the U S A have shown a great improvement in the ability of the pilot to fly on instruments when this type of instrument is fitted to the helicopter

3 NAVIGATION AIDS

Together with the development of the vehicles for all weather operations, considerable development has also taken place in the aids necessary for navigation and approach

The aid which has had the most development for use for helicopters is the Decca Navigator System The principles of this system will be well known to all of you here tonight so I will only briefly outline its advantages as a helicopter aid

Firstly, being a low frequency system it is not limited to line of sight range or subject to distortions or holes at low altitudes or in the presence of buildings all of which are most important when the low operating altitude (probably not above 3,000 ft) of helicopters is considered

Secondly, the area coverage it provides permits aircraft to fly a great multiplicity of tracks without a large number of ground stations This is particularly important if helicopter routes and operations develop to the density envisaged in the United States

Thirdly, the pictorial presentation of the Flight Log greatly simplifies pilot navigation and relieves the work load in instrument operation

Fourthly, the accuracy of the information provided to the pilot is very high and is probably on the average better than most other aids

Over 2,000 hours have been flown with current models of the Decca Navigator and Flight Log installed in British helicopters in both experimental flying and actual operations This flying has confirmed the inherent suitability of Decca as a helicopter aid The current installation is the Mark 8 which has shown a high degree of reliability in service Development of a more advanced equipment specifically for helicopter use in the 1960's is now under discussion

As with fixed wing aircraft, more than one navigation aid equipment is required in the aircraft to guard against failure of the primary aid What form the secondary aid should take is not yet determined The ANDB in the United States have shown that both V O R and A D F can be made to work in helicopters, though both are subject in some degree to rotor modulation The provision of some type of V H F aid would guard against simultaneous failure of two low frequency aids due to static conditions though the facilities it offered may be considerably less than the primary Decca system

4 INSTRUMENT APPROACH AIDS

Before considering approach aids in detail, I would like to show you some diagrams of the recommended I A T A helicopter site Fig 2 shows the recommended obstacle clearance limits around the site operating area which is 400 ft long and 200 ft wide You will see that the approach channel between the 1 in 2 obstacle slope line on either side of the site is relatively narrow and at break off height, 600 ft from the centre of the site, is only 500 ft wide Fig 3 shows the elevation profile of the approach channel The flight path of a helicopter approaching the centre of the site at a 20° glide path is shown At 600 ft from the centre of the site, the helicopter is 220 ft above the site level and 170 ft above the obstacle clearance line

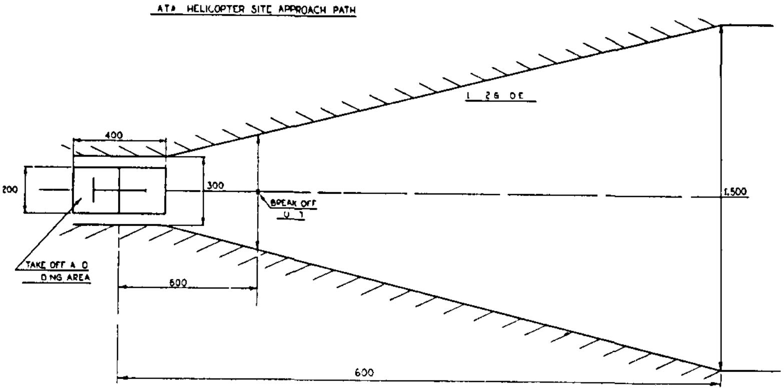


Fig 2

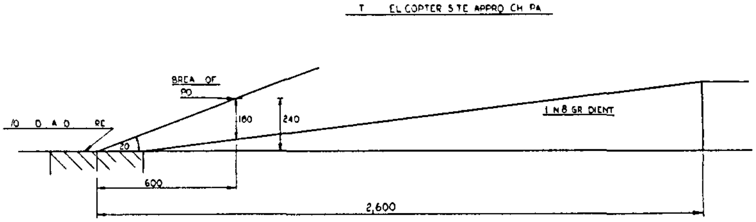


Fig 3

It should be emphasised that these diagrams represent recommended layouts and that the helicopter sites actually available in cities may be very much worse, or, and this is of course the more unlikely alternative, somewhat better than those shown

The problem therefore which the helicopter approach aid must solve is that of providing sufficient accurate information to the pilot of a large transport helicopter weighing approximately 40,000 lb to allow him to make an approach into a site some 200 ft wide by 400 ft long surrounded by large and valuable buildings in visibilities of the order of 150—200 yards To achieve an acceptable high approach success rate in these conditions the helicopter aid must have the highest possible accuracy and must allow the aircraft to be flown with the absolute minimum of deviations from the approach path

Approach aids are of two basic types

(1) Pilot-interpreted aids, *e g* , the Instrument Landing System and

(2) Ground-interpreted aids, *e g* , Ground Controlled Approach (Radar)

Contrary to popular opinion, the helicopter does not make a vertical instrument approach Although adequate stability can be provided in this flight regime by automatic stabilization, a helicopter descending vertically is very near the vortex ring condition Entry into this state is marked by heavy vibration, a partial loss of control and a very rapid increase in rate of descent from 1,000 f p m to 2,000 to 3,000 f p m This fact, together with the marked effect of wind and the high percentage of power required in vertical flight, has led to the steep approach concept

The steep approach, which is necessary to achieve a satisfactory obstacle clearance when operating into built-up sites, is made at a forward speed of 20 knots and a rate of descent of 750 f p m , giving an angle of descent of 20° The values of forward speed and rate of descent are chosen to avoid any likelihood of entering the vortex ring condition and to limit the vertical velocity of the helicopter so as to allow adequate time for the visual transition before landing

The rate of descent of 750 f p m means that the instrument approach from 1,000 ft is made in just over 1 minute, which demands an easily interpreted and accurate approach aid and a high degree of concentration and work load from the pilot

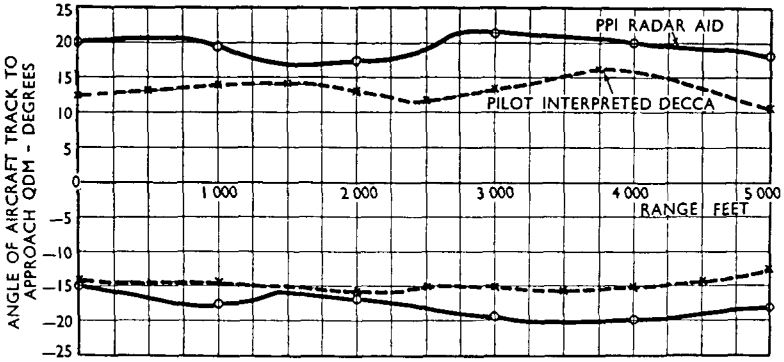
Quantitative tests of various types of approach aids have shown that the biggest problem is the effect of wind The helicopter with its slow orwardf speed is often approaching in conditions in which the wind strength is 50% or 75% of the approach speed In these conditions the changes in wind speed and direction which occur with change in height have a marked effect on the helicopter's flight path

Changes in wind direction, known as wind shift, require the pilot to make large heading corrections in order to achieve minimum track error Changes in wind speed, known as wind shear, necessitate large changes in rate of descent in order to stay on the glide path and also aggravate the effect of wind shift The difficulties are magnified by the high rate of the descent, necessary to achieve the obstacle clearance angle, which causes the helicopter to pass rapidly from one set of wind conditions to the next

Trials have shown that the prime requirement for an approach aid to meet these conditions is one with a high rate of information to the pilot The only type of radar aid which has come near to meeting this requirement is one with continuously scanning sector aerials for azimuth and elevation Unfortunately, the use of radar approach aids in built-up areas is subject to certain limitations regarding aerial location and the necessary complication of the equipment to avoid permanent echoes from surrounding buildings obliterating the helicopter target return For this reason, trials were also carried out on some pilot-interpreted aids

The majority of the tests of pilot interpreted aids so far, have used the Decca system as an approach aid In this technique the pilot flies down one Decca “ Lane ” towards the helicopter site using the intersecting lanes to measure the distance from touchdown and hence to derive a glide path These trials showed the marked improvement in the ability of the pilot to maintain the required track and heading throughout the approach compared with the much larger deviations which occurred when using a radar aid Some results from the initial series of Decca trials and some other trials using a radar aid with a rotating aerial and PPI display are shown in Fig 4

As a part of the evaluation of approach aids we have developed approach success criteria similar to that developed by BLEU for fixed wing aircraft Fig 5 shows that for azimuth success the two quantities are track displacement error and tracking angle error The solid lines are derived theoretically from the manoeuvres thought likely in this phase, whilst the more optimistic dotted lines are obtained from some preliminary flight tests, which had, however, the limitation of using small helicopters with an immediate transition for the pilot from full IFR to full VFR conditions at break off



TRACKING ANGLE ON INSTRUMENT APPROACHES

Fig 4

Obviously, the aid which gives the smallest track displacement error and tracking angle error at the end of the approach will give the highest approach success It appears that this is best achieved with the pilot interpreted aid because it gives a higher rate of information to the pilot than the ground radar type, as shown by the comparison of the PPI and Decca approaches In passing, I should mention that a glide path appears to be an essential feature of all helicopter aids

The Decca system at present is not universally suited for instrument approaches into a given site since the lattice line QDM is usually not aligned with the approach QDM We are therefore currently developing a technique which uses a very large scale Flight Log Chart on which the approach QDM can be drawn independently of lattice line direction

This equipment should permit Decca to be used as an approach aid at any site in Decca coverage though the meteorological limits in which it can be used at such will vary with Decca accuracy and in poor cover will be considerably higher than the 150 yards and 150 feet considered for this type of operation The Flight Log presentation is not ideal and if a meter presentation with the same independence of lattice direction could be developed it would probably be preferable

The variation of Decca accuracy plus the difficulty of generating a glide path from barometric indications in a helicopter has led us to initiate the development of a complementary aid to provide the very precise guidance necessary to get into that very small site when the weather is on the 150 yard limits

This is a centimetric beam ILS type aid which we hope will be developed from the Elliott Brothers Ltd , harbour course beacon of this type The advantages of a beam on these frequencies is that unlike the current ILS fixed wing equipment working in the VHF band it can be sharply focused to avoid buildings, etc , and thereby produce a straight undistorted beam

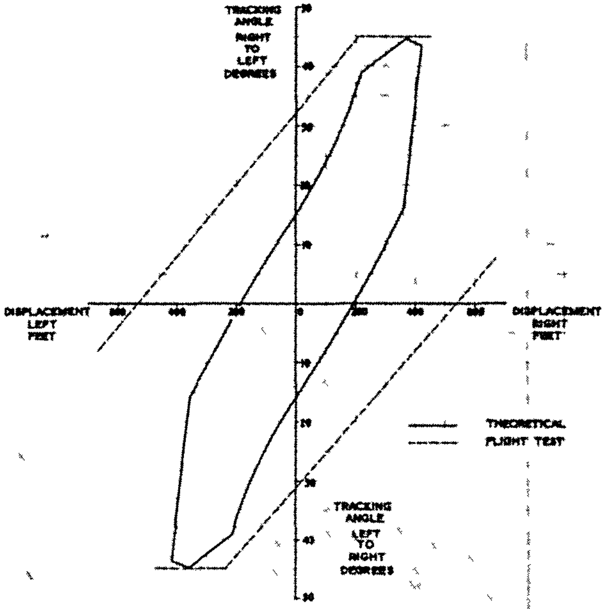


Fig 5

APPROACH SUCCESS CHART
I.A.T.A SITE 400 FT. x 200FT.

It should also be possible to design the airborne and ground aerial system so that any random reflections which may occur have a negligible effect on the received signal A further advantage is that transmitter and aerial systems for these frequencies are relatively small, and we hope, cheap !

With this type of beam it is relatively simple to use the signals in automatic pilot and flight director systems and eventually to develop an automatic landing system

We have recently finished an initial assessment of a very embryonic system, which was an adaptation of the marine beacon using aural signals only, with very favourable results Fig 6 shows the ground transmitter in these tests and gives some idea of its small size and the type of terrain over which straight undistorted beams were produced Those of you with experience of current ILS systems will realise the contortions which a VHF beam would tie itself into in the same site

A further trial of this equipment was undertaken at the South Bank when a series of approaches were made from a northerly direction past the Festival Hall and over Hungerford Bridge, both pretty formidable obstacles Despite the shortcomings of the present aural system a beam was produced which was straight and undeflected and untwisted by the presence of these obstacles I will now show you a film of these trials

Future developments include the inevitable sophistication of the equipment and the development of visual presentation

In additional to the equipment mentioned above, there are two other possible requirements for future large helicopters First, since wind speeds often exceed the proposed approach speed of 20 knots it may become necessary to make approaches at a constant ground speed This will require either a ground-speed indicator possibly derived either from a Doppler

Fig 6

radar system or a DME device or a ground speed control in the automatic pilot system which could be achieved by inertial means for very little weight

Secondly, the problem of flying on the " wrong " side of the power speed curve must be considered Future helicopters are likely to have minimum power speeds of the order of 60 knots so that in the approach phase at 20 knots the pilot may be called on to make large " unnatural " power corrections Here again some form of automatic control may be required

It must be emphasised that the elaboration of the above equipment is to enable the large helicopter to be operated safely in bad weather into the centre of cities If operation into relatively open fields or aerodromes is required, it is reasonably certain that the requirements would become less complicated

5 VISUAL AIDS

Having been guided by the approach aid and having arrived at 150 ft 150 yd away from the site, the pilot must change his control references from instruments to visual ones and land the helicopter To make his task as easy as possible in the 12 or 15 seconds available for this manoeuvre an approach and landing light pattern must be provided

The form which this pattern takes is extremely important since the pilot must make the transition from instrument to visual conditions with the minimum possible delay and the least risk of confusion Since the helicopter site lighting system cannot generally be extended downwind of the site, the approach and landing lights must be combined in one configuration which can be contained within the site, and this has a very definite effect on the type of lighting which can be used

As a result of experimental flying, a site lighting scheme has been developed which provides the following information

(*a*) Guidance during approach and take off on aircraft heading, longitudinal and lateral displacements and attitudes and approach angle

(*b*) Overall illumination of the landing area

(*c*) Distinctive definition and identification of the helicopter site and a delineation of the limits of the landing area

Early trials led to the conclusion that a rectilinear form of approach lighting would be the most suitable and eventually a form similar to the Calvert type of approach lighting used for fixed-wing aircraft was adopted The form of this pattern together with the other lighting found necessary for a site of the recommended I A T A dimensions is shown in Fig 7

The approach pattern is defined by semi-flush high intensity lights forming a " Cross of Lorraine " pattern with the upwind bar some 90 ft shorter than the downwind one For operation in the opposite direction, the short bar at the other end of the centre line is lit, instead of the one shown The lights forming this pattern would emit between 1,000 and 2,000 candelas in two reciprocal beams and a much smaller amount of omnidirectional light

The pattern is a very distinctive shape when viewed from the direction of approach and gives the pilot an immediate indication of the location of the landing area, his relative heading to it and his displacement from it Trials when night instrument approaches were made followed by transitions to visual conditions at 200 ft showed the pilot had little or no difficulty in orientating himself relative to the site

This pattern also provides the guidance necessary during the take-off period before the pilot goes on to instruments As an aid to steep approaches a three-colour glide path indicator has proved very useful and is positioned abeam the touch-down point, which is just downwind of the centre of the site

For the final stages of landing, it has been found necessary to light the ground preferably by floodlights to give the pilot a good indication of the ground plane by means of textural guidance To obtain the necessary degree of textural guidance, the ground is painted in a form of lattice or chequer-board marking In the proposed scheme these lights are placed on the downwind boundary pointing upwind

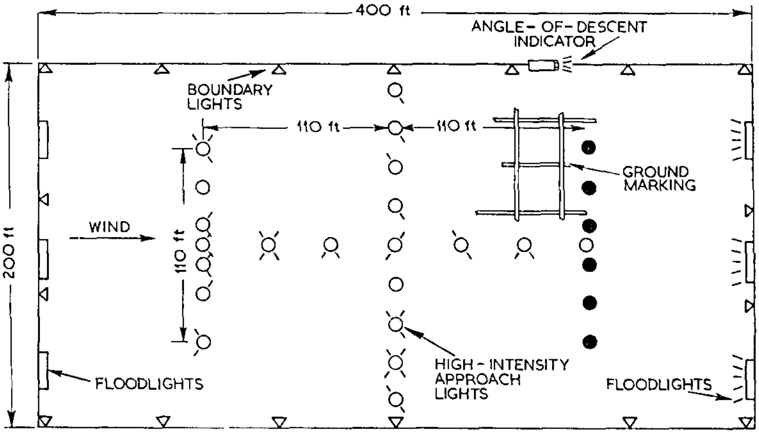


Fig 7

Finally, the boundaries of the landing area are marked by low-intensity blue flush lights similar to airport taxiway lights

I would now like to show you a rather rough short film of a series of helicopter approaches onto this lighting pattern The main lights which show up are the approach lights but you will also see the angle of approach indicators and the air navigation beacon

A problem which has yet to be solved is the control of the glare in the helicopter's cockpit whilst landing amongst this array of lights, especially in fog or haze This will require the careful planning of all site lighting and may demand a sophisticated method of varying light intensity

6 Air Traffic Control

As I am in no way knowledgeable about Air Traffic Control, except inasmuch as they always try to stop me doing what I want to do, I can only make some brief generalisations

Obviously, any helicopter A T C system must be compatible with the fixed wing system

It would seem that the objectives of the helicopter system would be two fold, namely (*a*) To achieve safe separation and regularity of operation of helicopters within the framework of helicopter operations and

(*b*) To ensure separation of helicopter and fixed-wing operations

It is not possible to draw any definite conclusions on helicopter A T C until traffic has reached much higher figures than today, but some tentative statements can be made Initially, helicopter separation and control will probably be by means of ground-based surveillance radar in conjunction with the Decca Navigator system carried in the aircraft This would seem adequate in Great Britain at least for some considerable time

If traffic grows to the proportions considered likely by I A T A it will be necessary to adopt their proposed system of parallel track separation This system calls for very close lateral separations and will necessitate development of existing navaids if it is to be implemented with safety

The separation of helicopter and fixed-wing traffic has been the subject of experimental and service flying at London Airport As before, only tentative conclusions can be drawn about future trends It would seem that altitude separation will be the main method of separation on scheduled routes with the helicopters taking the lower strata A particular point which has already been established is that when entering a fixed wing aerodrome the best method for the helicopter is to cross the duty runway at right-angles, which has a negligible effect on runway occupancy time

6 CONCLUSIONS

In this lecture I have tried to describe the basic elements of a framework of aids which will permit all weather operation of transport helicopters at the end of 1960 None of the equipment described is of a radically new nature, with the possible exception of the centimetric ILS system, but all of it still requires considerable development if it is to be available in production or pre-production form at the same time as suitable civil helicopters appear in airline service in 1960 Unless this development is undertaken both by operators and manufacturers it will mean that the usefulness of these aircraft will be limited and the full potential of the transport helicopter will not be realised

ACKNOWLEDGMENTS I should like to thank British European Airways for permission to give this paper The views expressed are my own and do not necessarily reflect those of the Corporation

Next, I would like to mention what must be obvious to all of you, that the development work I have described is a team effort which started in 1948, and in which I have only participated during the last three years I would like to pay tribute to the other members of the team and in particular the members of the original B E A helicopter group and the pilots past and present of the Helicopter Experimental Unit