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Some Present and Future Aspects of Helicopter Piloting

By Capt J S FAY

A paper presented to the Helicopter Association of Great Britain, on Saturday, 25th November, 1950, in the Library of the Royal Aeronautical Society, 4 Hamilton Place, London, W 1

Introduction by Mr O Fitzwilliams

Introducing Captain Fay, Mr Fitzwilliams said it would be generally agreed, that very few people, if any, in the world were better able to discuss the subject The lecturer held the rank of Captain in British European Airways, and had served with the Helicopter Unit of the B E A since its inception in 1947, when it was based on Yeovil, and when the Chairman had had the pleasure of meeting him and his colleagues The activities of that Unit had covered a very wide range of helicopter operation, including an intensive pioneering effort in helicopter blind flying

As a Fleet Air Arm pilot he had learned to fly in 1940, and had served for two years in H M S "Victorious" Afterwards he had joined the Naval Service Trials Unit, and was converted to helicopters at the first helicopter training course in this country, at Hanworth, in 1944

From that very wide background of experience he had prepared a very interesting paper

CAPTAIN J S FAY

Introduction

This afternoon I shall discuss some of those features associated with piloting which are peculiar to the helicopter

The views expressed are my own, and are not, therefore, intended to be representative of piloting opinion in this country

I should point out that my own experience of rotary-wing aircraft is confined to the R 4, the American S 51, and the Bell 47B , but I have had short flights in the C 30, the Hiller 360, and the Bristol 171 Because of my limited experience of up-to-date helicopters, there will, no doubt, be people with more recent knowledge who will be able to speak with more authority on certain matters In this case I hope they will join in the discussion afterwards

The Paper is divided into seven sections

Controls	Emergency Landings
Navigation	Pilot Comfort and the Problem of Pilot Fatigue
Instrument Flying	Pilot Training
Night Flying	

SECTION I

Helicopter Controls

For a pilot to be able to fly accurately and with a full command over his aircraft at all times, the controls must have a fairly self-evident direction of movement and must be reasonably light to move, while the response of the aircraft to any control movement must be positive and immediate In some cases it is also desirable for the controls to have a certain amount of " feel " to enable the pilot to become instantly aware of any change taking place in operating conditions

It is with these factors in mind that I discuss the present control systems of the helicopter

First of all we will take the control with which the pilot has to do most of his work

The Cyclic-Pitch Stick This control acts in a completely natural sense, but it varies with different types of aircraft in its degree of lightness The heaviest with which I have flown is the one in the S 51, while the lightest is the one in the Hiller 360 The stick-force required in the S 51 is sometimes of the order of 20 lbs for fore and aft movement and 15 lbs for lateral movement, which is obviously too great for ease of control for a manoeuverable aircraft When sudden large movements are needed against both the trimmers and the big forces transmitted back through the control system to the stick from the rotor during gusty weather, the strength required to maintain control becomes even greater

The lightness of control is not only of importance to the pilot for full manoeuvrability and control of the aircraft, but is also a factor in the pilot-fatigue problem to which I refer later

The trimming of stick forces in the cyclic-pitch stick is usually carried out by adjustable springs or bungees which are attached directly to the control linkage at a point somewhere between the pilot's stick and the swash plate A matter to ask of the designers is that they ensure that the trimmers have ample range to cope with all c g positions including the case where it is off-set laterally, and all possible operating conditions This may sound elementary, but it is not always done

In the fixed-wing aircraft the trimming system is such that, to a certain extent, the aeroplane can be controlled by the trimmers alone The trimming

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tabs have their own control wires all the way from the cockpit If the cables to the normal control surfaces were to fail for any reason, the trimming tabs could be used to fly the aircraft and save it from becoming immediately out of control, and when flying a fixed-wing aircraft I have always felt a certain security about this fact With the present methods in helicopters this is not possible, owing to the trimming system acting on the control transmission near to the source of movement I should like to see the design of a trimming system that actually worked on the blades themselves, or, if that is not possible, as near to the blades as practicable, on the swash plate if there is one, for example This would give the pilot a greater feeling of security, and if the control system did fail for some reason, such as an unexpected fatigue failure in a prototype aircraft or due to enemy action in wartime, he would have a good chance of landing safely

Whatever system of trimming is used, it must be a positive one and act immediately the pilot works the gear In addition, there must be no back-lash or looseness when the trimming direction is reversed

The response to movement of the cyclic-pitch stick varies in different types of helicopter The stick in the S 51 has quite a time-lag after movement, while I was pleasantly surprised to find that the response to the stick in the Bristol 171 was immediate, in fact it resembles the response of a fixed-wing aircraft, which is what we want

The Collective-Pitch Lever The collective-pitch lever acts in a completely natural sense in that to go up you pull it up and to go down you push it down Response to movement of the lever is immediate, provided that sufficient power is available for the weight of the helicopter

The force required to move the lever in the S 51 is about 17 lbs with the friction nut loose In normal cruising flight the lever is not moved very often by the pilot, so this comparatively large force does not cause any undue hardship For crop dusting and spraying, however, the collective-pitch lever is moved constantly, and with a heavy control the arm is apt to tire easily A light lever would be greatly welcomed for this sort of work

And now a contentious point in a side-by-side cockpit is there to be only one collective-pitch lever ?

Some people say that as the captain of an aircraft should sit on the left, there should be just the one lever located between the two seats, which he can let go when he wants to manipulate the various knobs and switches usually found in the centre of the cockpit

On the other hand others say that for hundreds, or thousands, of hours they have flown with a control column in their right hand and a throttle in their left To change would mean getting used to the feel of the control all over again, in fact they could never quite attain the same standard It would be like a right-handed person learning to write with the left hand , eventually after practice he could write almost as well, but he would never feel quite so happy as he did when using his right hand

I believe that for a right-hand person the cyclic-pitch stick is the natural one to have in the right hand Even though I was initially taught to fly an R 4 on the left of the cockpit, changing over to the right-hand side after some twenty hours flying, I always preferred the latter side with the collective-pitch lever in the left hand

The solution to the whole problem, if it cannot be settled definitely one way or the other, is to have two collective pitch levers, one on each side of the left-hand seat so that the pilot can take his choice

Throttle The best-known throttle at present is the twistgrip type This is a neat and tidy arrangement of reasonable mechanical simplicity An easy wrist movement is required to work it, and the pilot has little difficulty in locating it quickly if necessary should his hand be taken off temporarily to fiddle with switches Its main drawback is that it does not act in a natural sense, so it is the one control that new pupils tend to move the wrong way Another trouble is that it is not possible to tell by its feel or position just how far open it is A further slight disadvantage is that the rotary movement required is the exact opposite to the resulting movement of the r p m indicator on the instrument panel

A different type of throttle is found in the Hiller 360 In this aircraft the throttle is in the form of a lever mounted alongside and to port of the collective-pitch lever and it is moved up and down manually together with the pitch lever The advantages of this type are that it is possible to tell by feel the relation of power to pitch setting, therefore much less attention need be paid to the tachometer , and it acts in a natural sense One disadvantage is that there are two separate levers to move and they are rather uncomfortable to hold Another is that when holding both levers the rotary action of the wrist to open the throttle is the exact opposite to the action of the twist-grip type, so a pilot who has to fly separate types of helicopter with different throttles may get confused

A third type of throttle, the principle of which I like, is the spade-grip type as used in the Air Horse This type is rotated round an axis which is at 90 degrees to the collective-pitch lever to which it is attached To a certain extent it operates in a natural sense in that it is moved clockwise to open and therefore moves the same way as the tachometer needles Like the Hiller throttle it is possible to refer to its position by feel and obtain an estimation of the power setting at any time

When considering helicopter throttles it must be remembered that a great deal depends on the relationship between throttle movement and the resulting change in the butterfly setting in the carburettor If the relationship is too sensitive, the slightest movement of the wrist will cause a gain or loss of too many revs, and the pilot's task will be difficult, if not dangerous If, in addition, the throttle is rather stiff to move, then a great deal of concentration will be required to maintain the correct revs It is most desirable for there to be a well-chosen relationship between hand movement and the change of r p m , and the throttle must be light with some sort of friction device incorporated to enable the pilot to tighten it as he wishes

With the intention of giving the pilot one less control to manipulate, other ideas which concern the throttle are being tried out The first of these is the type of helicopter which has an automatic pitch-change device In this, when the throttle lever, which is similar to the normal type of collective-pitch lever in appearance, is raised, the torque tends to increase without an appreciable change in r p m , the blade angles being automatically increased by their movement about " delta three " or " alpha one " hinges Another way of doing practically the same thing is to use centrifugal weights which fly out with the increase in r p m that results from an opening of the throttle, in doing so they alter the pitch setting of the blades In this case the r p m must have some appreciable variation

From the safety aspect, in single-engined aircraft these ideas are most praiseworthy as they become an automatic pitch reduction device in the event of power failure In their simplest form, however, they have one or two drawbacks There is no " cushioning " control available for power-off landings, and there is no means of adjusting the pitch setting for height compensation In more advanced versions these difficulties are overcome by the incorporation of over-ride mechanisms

With one less control to operate, the helicopter will be more suited to the private owner, and so long as the unique characteristics of the helicopter are not impaired the commercial pilot will have all the control he needs for his operations, while blind flying will be considerably easier for him On the other hand, although my experience of crop dusting is limited, I feel that the crop-dusting pilot will prove an exception Operating as he does close to the ground at moderate speeds he will require an up-and-down control that acts immediately it is applied in order to avoid hitting the ground in gusty weather

Yawing Control My experience is limited to helicopters having a single main-rotor In these types where the blades are driven at the root ends by the conventional engine, the tail rotor is the well-known means of balancing torque Movement of the aircraft about the normal axis is provided by the increase or decrease in the tail-rotor moment that results from an increase or decrease in tail-rotor pitch at constant r p m The pilot's control for this consists of pedals similar to those in fixed-wing aircraft

This control is a powerful one and there is an almost negligible lag between the time a rudder pedal is depressed and the time the tail starts moving However, I should like to ask that the pilot be given a little more freedom of control than the present designs allow for

I feel that at its maximum weight the helicopter should be capable of being rotated through 360 degrees about its normal axis against rotor torque in winds up to 20 m p h , and that in autorotation it should be possible to rotate in the opposite direction to the rotor when flying at 20 m p h In giving these figures I do not want it felt that a pilot will necessarily require to do these things, but rather that he feels he has that extra reserve of control available In this way the rudder pedals will not come up against the stops quite so early as they do with present designs

In contra-rotating co-axial systems the more usual method of control in yaw is by applying a greater or lesser collective pitch to one of the rotors, the resulting change in torque tending to rotate the fuselage Both this and the tail rotor system have much to commend them to pilots because of the quick and powerful response

In the case of twin or multi-rotor configurations, control about the normal axis may be carried out by a differential cyclic-pitch change being applied to a minimum of two rotors Unfortunately I have no experience of this type of helicopter, and can only surmise that for multi systems of moderate size the time-lag which there must be is not sufficiently great to cause serious worry to the pilot As the multi system gets bigger it may well be that the differential cyclic-pitch yawing control will give way to an auxiliary rotor or airscrew used entirely for control in the yawing plane

SECTION II

Navigation

Day

When flying across country by day the helicopter pilot usually relies on map reading for his navigation, or he knows the route by memory from previous flights carried out by reference to a map

The technique of the helicopter pilot differs from that of the fixed-wing pilot when map reading because helicopters usually operate close to the ground At this height there are some attendant difficulties and it is generally found that fixed-wing pilots on helicopter conversion courses do not properly appreciate the fact until they have made one or two cross-country flights The aeroplane pilot flying at a height has a wide field of vision and can see large areas of country, many towns and long stretches of river Except on days of very good visibility, the helicopter pilot, who usually flies at 1,000 feet above the terrain, is more concerned with villages or cross-roads or small stretches of river Churches and windmills are a help , so, of course, are the ever-useful railways, and the helicopter pilot is additionally fortunate in that he can sometimes read the names of the stations

Putting it another way, the helicopter pilot examines small patches of countryside closely, instead of gaining a general impression of a large section of the country

An added difficulty for the helicopter pilot, which also applies to the pilot of slower aeroplanes, is that when flying a given track he must make much more allowance for the wind than the pilot of the faster types of aircraft The slower the aircraft, the greater does the angle between track and course tend to become

At present, given a reasonably accurate forecast wind, it is possible to fly a given track, picking up pin-points and adjusting the course accordingly But when the helicopter has no D I to assist the pilot's interpretation of the compass, difficulty is experienced in flying a fixed course, especially in rough weather, because of the never-ceasing changes of indication due to acceleration errors, turning errors, and small swings of the fuselage In addition, when visibility is below one mile and the country is strange to the pilot, it becomes difficult to maintain a pre-determined track, for one cross-road or village can look much like any other In this case it is usually simpler to fly along a railway line or main road

A map is such an important item of equipment that it is well to ask whether the present maps are satisfactory for helicopter pilots

For general navigation over Britain the helicopter pilot is only concerned with the $\frac{1}{4}''$ map, and on the whole this is satisfactory I would, however, like to see the following improvements to it

Firstly, I should like to see the runways, or in the case of grass aerodromes the boundaries, of aerodromes marked on the map At present, aerodromes, irrespective of their size, are marked by two small red circles of $\frac{1}{8}''$ total diameter Even supposing that the average runway were only half a mile long and represented by $\frac{1}{8}''$ on the map, there is ample room to insert representation of the runways In making this suggestion I am thinking of the number of times I have been in country new to me, and have flown over a disused aerodrome or seen another one in the distance and been unable to identify it positively Here I should add, for the benefit of people who rarely get the chance of a flight, that Britain is positively littered with aerodromes, especially in flat areas like East Anglia

Secondly, all high-tension cables that are more than one mile away from towns should be marked This would not only aid navigation but would also prove of value in planning and executing crop-dusting operations

Thirdly, where possible all railway stations should be named At present, many are marked but not always named

Fourthly, the marking of woods should be brought up to date with changes which have taken place , at present they often prove more misleading than helpful

A word now about pure D R navigation—when flying over the sea for example It is possible for the helicopter to be in a slightly yawed condition in flight without the pilot realising it, this is especially true if, for any purpose, the aircraft is required to fly slower than the normal cruising speed For this reason the helicopter should be fitted with a sensitive yawmeter as additional navigational equipment

Night

Navigation in a helicopter, especially at night, is restricted because of the instability of present helicopters The pilot can never let go the cyclic-pitch stick to plot QTE's or work out his position from Decca co-ordinates His attempts at positive navigation are usually restricted to D R , having previously worked out his courses on the ground, aided by such familiarity with the route by day that lights seen at night can be associated with the known position of a town or village This pre-supposes that the pilot is not flying in cloud and that visibility is fair In order to fly to a predetermined place, a homing system can be employed and in the BEA Helicopter Unit two systems have been used an Omni-Directional Beacon , and normal VHF D/F One can also place under the heading of " homing systems " the identification beacons and the various types of pyrotechnics which can be fired from the ground should the pilot need them

Day and Night The Future

The disadvantage of a homing system is that it is not a positive form of navigation A pilot cannot point to a place on a map and say to himself " I am *there* " When map reading, he is sometimes in the same straits if the countryside happens to be featureless, or if he is not sure of his position after the incorrect interpretation of some landmark due to there being several of a similar sort in the vicinity

What the helicopter pilot requires is some system whereby he is shown exactly where he is the whole time, without his having to do much thinking, and with very little manipulation of knobs and switches

It is fortunate for us in this country that with helicopters on the threshold of operations where accurate navigation will be required, an exact and almost foolproof system of navigation is about to reach the production stage I refer, of course, to the Decca Flight Log

Members will probably be familiar with the normal system of Decca navigation whereby, to use simple language, the aircraft's position is interpolated on a map after reference to the readings of three dials (decometers), which, in their turn, receive continuous information from a network of radio stations covering the country In the Flight Log, the interpolation is done for the pilot automatically A pointer moving over a map shows the present ground position of the aircraft at all times and leaves a mark on the map of the ground which has been flown over

Thus for the first time, pilots will have an apparatus which will give them an accurate presentation of their ground position without their having to make any mental calculations and without their having to take their hands off the controls

SECTION III

Instrument Flying

My experience of flying helicopters by instruments is limited to the S 51 aircraft, so my remarks must be taken as applying mainly to that type of helicopter The S 51, as most of us are aware, is a single main-rotor helicopter of 5,300 lbs all-up weight, with a torque-balancing tail rotor The controls are heavy for an aircraft of its size and the aircraft is unstable, consequently it is fairly tiring to fly under daylight contact conditions Under instrument flying conditions the difficulties do not multiply quite as much as one might expect, and some of the increase in fatigue is due to the fact that the pilot tends to fly much more accurately when on instruments than he does normally

Part of the strain of instrument flying is caused by the eye having to move continually over the instruments Much fatigue can be eliminated, and instrument flying made easier, by careful positioning of the instruments in the panel In determining these positions two factors stand out above the other considerations These are the relative importance of the instrument in enabling the pilot to maintain control , and the distance the eye has to move when obtaining the information from the dial itself In the first case it is obvious that the artificial horizon should command a central position In the second case an instrument such as the rate-of-climb indicator, in which the pilot is only interested in the extreme left-hand side of the dial, should be somewhere on the right-hand side of the panel, in this way an unnecessary movement of the eye right across the face of the dial is eliminated

Instrument flying at speeds over 40 m p h

The instrument panel used by the B E A Helicopter Unit for the night mail contract last winter is shown on page 145

It will be observed that the turn and side slip indicator found in aeroplanes is dispensed with, but a slip indicator in the form of a ball in a curved tube is retained With their position in the panel as shown, the needles of the r p m indicator and manifold pressure indicator point towards the centre of the panel when the aircraft is flying, thus making the pilot's eye movement an inch or two less than if they pointed away from the centre The usual type of Direction Indicator is used I prefer this type myself, not only because I am used to it, but in the plan-view pictorial representation type I have to change my mental picture of the aircraft in space from the picture I get when looking forward to one in which I am looking down on the aircraft from above

At this stage it is worth reviewing how helicopter flight, as it applies to instrument flying, differs from that of fixed-wing aircraft

(1) The helicopter has a pendular swing, mainly longitudinal, under the rotor, thereby making control movements somewhat more complex than those required in fixed-wing aircraft
(2) Due to the pendular swing, and for other reasons, the helicopter is markedly unstable
(3) There is a time-lag in response to movement of the main control—the cyclic-pitch stick
(4) The attitude of the fuselage often bears little relation to the flight path of the helicopter
(5) Compared with the aeroplane, the helicopter has an extra flying control —the collective-pitch lever
(6) A change of power means a change of torque, and therefore a tendency to swing in the yawing plane

B E A helicopter instrument panel for night flying

I shall now take the instruments as fitted to the B E A panel and discuss their reactions, and application to blind flying in an S 51

Artificial Horizon

Because of the time-lag to the fuselage following stick movements, an instrument that has no time-lag, such as a gyroscopic instrument like the artificial horizon, assumes an extra importance when used in a helicopter An artificial horizon is essential to a helicopter for blind flying and it is impossible to fly for more than a few seconds without it in turbulent conditions Because of its extra importance, the Helicopter Unit fitted two of these instruments to the blind-flying panel so that if one should have a catastrophic failure the pilot could use the other one for the remainder of the flight The problem of knowing which one of the two has failed can be

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solved by flying the aircraft level on a constant heading with nil slip The faulty instrument should then be revealed by its inconsistent reading

Taking each of the halves of the artificial horizon in turn we have

The Fore and Aft movement of the Artificial Horizon

This section of the artificial horizon is the most important of any of the instruments , for once a series of longitudinal swings or over-corrections occur, the only instrument that will tell the pilot what he wants to know is this one because it immediately shows the longitudinal position of the fuselage

Compared with the one in a fixed-wing aircraft, the little aeroplane in the instrument can take up some alarming attitudes, especially in bumpy weather , however, one soon becomes accustomed to this

One of the disadvantages of our present type of adjustable fore and aft datum on the instrument is that in the extreme position of the little aeroplane the longitudinal information supplied, although correct when the helicopter is level laterally, is erroneous when any degree of bank takes place Alternative forms of adjustment, such as having the whole instrument box or the panel itself adjustable, would probably overcome this problem In addition, the present form of adjustment is not sufficient to look after the wide changes in longitudinal attitude which alterations in c g position can cause, and these alternative forms of adjustment should overcome this difficulty also

Because of these errors, and others possibly associated with the pilot's unwillingness to alter pitch and throttle settings when turning, all turns should be constantly checked with the rate-of-climb indicator for loss or gain of height

Lateral Movement

Owing to the visual picture presented by the artificial horizon it is, as most pilots will agree, a very pleasant instrument with which to work The single-rotor helicopter is less unstable laterally than longitudinally, and the reaction of the roll section of the artificial horizon does not differ in any way from that of fixed-wing aircraft, so I need not elaborate on it here

Direction Indicator

The ordinary Sperry type is used in the B E A Helicopter Unit and the reaction and interpretation of it does not differ very much from one fitted to an aeroplane It is more difficult to steer an accurate course by it in a helicopter, especially in bumpy weather, but not unduly so When altering power or speed, the aircraft heading, and therefore the directional gyro indication, will start to wander, owing to torque changes and fuselage weather-cocking effect, unless the rudder-setting is changed as well In a climb or descent the pressure of the legs required to hold the helicopter straight becomes very noticeable after a minute or so—more so in fact than when flying under contact conditions I think this is because one is tending to fly more accurately when on instruments

Slip Indicator (Ball)

The ball aids the checking of the artificial horizon, and of course is useful for telling the pilot whether he is side-slipping In a helicopter one tends to side-slip more than in an aeroplane due to torque changes associated with alterations of power

Rate-of-Climb Indicator

Due to the position of the static vent this can be quite a sluggish instrument Even so it is a most important one due to the possible large angles between fuselage attitude and flight path It completes the mental picture formed in the pilot's mind as to what the aircraft is actually doing

For example the artificial horizon could show a nose-down attitude, the A S I a speed of 90 m p h , thereby giving an initial impression of a dive , or, conversely these instruments could show a nose-high attitude and 50 m p h respectively, giving an impression of a climb Despite these impressions a glance at the rate-of-climb indicator could show that in both of these cases the aircraft was in fact flying *level*

Air Speed Indicator

Interpretation of the A S I does not differ very much from that of fixed-wing practice There is a slightly longer time-lag following movement of the cyclic-pitch stick to alter the longitudinal attitude of the aircraft, and therefore the speed, than there is the fixed-wing aircraft The helicopter pilot undergoing a course of blind flying should not experience any difficulty in using the A S I under blind-flying conditions, for he has already had practice in its use and can anticipate the time-lag between stick movement and the resulting change of speed

Altimeter

The application is no different to that of fixed-wing aircraft The prospect of fitting a radio altimeter to helicopters is one that most pilots look forward to In addition to the safety aspect, a radio altimeter will be needed more often in helicopters than it is in aeroplanes, due to the fact that helicopters generally fly much lower than fixed-wing aircraft

Compass

The application is the same as in fixed-wing aircraft , but a compass has more tendency to wander in a helicopter, readily picking up swings and yawing movements and exaggerating them

Manifold Pressure Gauge and Combined Engine and Rotor Rev Indicator

These instruments are not, strictly speaking, blind-flying instruments, but they are, of course, absolutely essential for instrument flying so are included here

The most noticeable point about their application is that when the collective-pitch lever and throttle positions are being altered it is necessary to take one's attention off the blind-flying instruments and concentrate momentarily on the revs and manifold pressure

Fortunately, for normal flying, large movements of the pitch and throttle are not usual For training purposes, however, they often are, and probably the most exacting instrument-flying manoeuvre is one associated with big power changes such as the transition from an autorotational descent to a climb

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On the rev indicator, the fact that the movement of the needle over the most essential range of revs is a slight one—about a quarter of an inch—tends to increase unduly the concentration required for this instrument A larger scale for the instrument would help things considerably

General

It is, of course, more difficult to fly an S 51 on instruments than a comparable fixed-wing aircraft As I state elsewhere, one of the greatest aids to blind-flying would be for the helicopter to have some positive dynamic stick-free stability in cruising flight

The Future Instrument Flying at Speeds from 0 to 40 m p h

Why should it ever be necessary for helicopters to be flown by reference to instruments at speeds under 40 m p h ?

As the more advanced helicopters come along, it will become more and more important for helicopters to be capable of landing and taking off in conditions of bad visibility so as to maintain a regular schedule The helicopter normally touches down on a very small area of ground, therefore an accurate and necessarily slow approach must be made to the landing site, so the blind-approach system used in the future must be able to cope with the slow-speed approach A second consideration is that future rotor-stations are likely to require a steep approach to them in order to avoid high obstacles in the vicinity The steeper the approach, the slower must be the approach speed, and in bad visibility conditions the approach must be carried out on instruments Thirdly, the transition from the hovering position to the normal climb must be slow until the usual climbing speed is gained, in foggy conditions it must be carried out by reference to instruments in the same manner

At present, even with the instruments described previously, it *is* possible to carry out a blind transition from the hovering position to a normal climb, provided that there are no obstacles in the vicinity and so long as the pilot maintains full power and a positive rate of ascent, keeps the airspeed increasing positively until the normal climbing speed is reached, and flies the aircraft so that it is level laterally and has no side-slip It can be seen in this case that no exacting precision flying is required of the pilot, and that the helicopter is quickly brought to normal climbing condition where he can employ the usual technique

Let us now examine the reasons why at present it is not possible to carry out normal manoeuvres at speeds below 40 m p h under instrument-flying conditions with the normal instruments

(*a*) More control movements are necessary for precise flying, and the tendency to over-control increases

(*b*) There is a marked increase in possible differences between fuselage attitude and flight path, and the correlation of the artificial horizon, rate-of-climb indicator, and the A S I in order to obtain a mental picture of the flight path is not possible when these differences are too marked

(*c*) The directional stability of the helicopter decreases as speed falls off, and there is no instrument which can tell the pilot in which horizontal direction the helicopter is moving through the air (*d*) Although the effect is momentary, a gust tends to produce a relatively larger change to the indicated airspeed

(*e*) In slow-speed descents, when the angle between the fuselage and the flight path is greatly increased, the present A S I becomes inaccurate because the pitot head is not facing directly into the airflow

(*f*) Translational lift is lost at slow speeds, and an accurate and immediate indication of changes of motion in the vertical plane is required by the pilot, which is not given by the present type of rate-of-climb indicator where the static vent can be adversely influenced both by rotor down-draft and the motion of the fuselage through the air

(*g*) In vertical, or near-vertical powered descents, considerable disturbance is met when the helicopter is flying through its own downdraft

Taking these and other matters into consideration, we can lay down some requirements which helicopters must have to enable them to be flown by reference to instruments at slow speeds

(1) The helicopter should have a good measure of stability about all three axes at slow speeds and when hovering Fewer control movements would then be necessary, gusts would have less effect on the helicopter as a whole, and the consequence of the disturbance encountered in vertical powered descents would not be so great

(2) There should be an indication of the helicopter velocity relative to the air in the horizontal plane , in addition, indication should be given of any tendency of the helicopter to change direction and speed In the United States, a system whereby the angle of tilt of the plane of the rotor disc relative to the horizon is measured continuously, and indicated to the pilot, has been used with some success

(3) The accuracy and sensitivity of the rate-of-climb indicator, as fitted to helicopters, must be increased

These are the primary requirements, but one or two others can be added, especially when helicopters will be required to carry out blind approaches These are

(i) The helicopter should have one less control If the throttle and collective-pitch lever could be combined into one control, the pilot would have a less exacting task

(ii) A radio altimeter should be fitted

(iii) There should be an accurate indication of translational motion relative to the ground At present, I visualise the instrument as a form of the Decca Flight Log

SECTION IV

Night Flying

Like the section on instrument flying, my remarks on night flying are based on the work of the B E A Helicopter Unit with S 51 aircraft

The ways in which night flying in helicopters differ from night flying in aeroplanes are mainly concerned with the approaches and landings to small sites as opposed to large aerodromes Much of the remainder of the night-flying problem is the immediate concern of designers and engineers in adapting aircraft that were originally designed for day flying to a condition where they can be used for night work Accordingly the field open for me to dıscuss ıs lımıted , I shall therefore consıder only the take-offs and landıngs and the equıpment especıally concerned wıth these

Take-offs

As a bare mınımum the pılot requıres to see the ground sufficıently to take off and hover prıor to the clımb away The starboard navıgatıon lıght gıves enough ıllumınatıon for thıs purpose However, ıt ıs not always desırable to do thıngs the hard way, and basıc ground equıpment should ınclude the provısıon of lıghts strong enough to enable the texture of the ground to be seen reasonably well when hoverıng at a heıght of 50 feet

The sequence of takıng off and attaınıng a normal clımb should be as follows After leavıng the ground a vertıcal clımb should be carrıed out to a heıght of 50 feet, the cyclıc stıck then be pushed forward and a translatıonal clımb at normal speed commenced

The object of the vertıcal clımb ıs a twofold one When the stıck ıs pushed forward to attaın translatıonal flıght, some lıft ıs lost and the aırcraft tends to sınk A loss of ten feet from a heıght of 50 feet does not matter, but a loss of ten feet when the aırcraft ıs low, and has just moved from a lıghted patch of ground to a dark patch wıth the pılot not fully aware of the amount of heıght he has lost, could prove dangerous The second consıderatıon ıs the one of engıne faılure I would rather have an engıne faılure when hoverıng at 50 feet over a *lıghted* patch of ground than when movıng forward at say, 20 m p h at 20 feet over dark ground I realıse that ın sayıng the pılot should clımb vertıcally to 50 feet, one of the rules about not hoverıng or clımbıng vertıcally between 20 feet and 400 feet ıs beıng broken But ıf the pılot ıs alert for engıne faılure, and ıs quıck ın hıs reactıon to ıt, he has a better chance of walkıng out from the arrıval on the ground than he would otherwıse have

It should be mentıoned here that, ın some cases where the nature of the ground permıts, ıt ıs possıble to ıllumınate that area of ground whıch ıs up-wınd of the take-off poınt However, B E A ıs lookıng to the future, and ıt ıs certaın that there wıll be many sıtes where ıt wıll not be possıble to ıllumınate the ground fully

Landıngs

Normal landıngs at Sıtes In order to land easıly and safely at nıght, the pılot must know the wınd dırectıon , he must be able to see the ground, preferably wıth the aıd of lıghts on the ground and not by usıng the aırcraft lıghtıng , and he must be able to obtaın from the ground lıghtıng an ındıcatıon of the horızon so as to enable hım to retaın the aırcraft level laterally when not lookıng at hıs ınstruments

Members of the Assocıatıon wıll be famılıar wıth B E A 's " Wıggımac " , an approach aıd ıncorporatıng a wınd ındıcator, and a lıght whıch ıllumınates the ground sufficıently to enable a landıng to be made Naturally ıt ıs also used to enable normal take-offs to be carrıed out

The " Wıggımac " does not gıve an ındıcatıon of the horızon necessary for landıng and ıt should be augmented by a lıne of lıghts placed at rıght angles to the wınd In the Helıcopter Unıt we use lıghts arranged ın the form of a " T " and, ın order to gıve the pılot some assıstance ın judgıng dıstance and heıght, a cırcle of lıghts ıs placed round the " Wıggımac "

The actual helicopter night approach is similar to the type used in daylight The same approach angle is used and the aircraft is landed in the vicinity of the " Wiggimac "

Emergency Landings at Night In the case of engine failure in a single-engined helicopter at night, it is necessary for the pilot to be able to see and choose a landing area, and then to touch down visually Both these requirements point to the need of parachute flares

For night operations, the aircraft in the B E A Unit are fitted with two parachute flares which are mounted externally They are fired singly and electrically by the pilot and are carried well clear of the rotor blades by a rocket before the parachute opens and the flare ignites Fortunately these have not had to be used in a real emergency, but some practice autorotational approaches have been carried by the aid of their light It would seem that the best methods of using them in the event of real engine failure, assuming that the aircraft is at about 1,000 feet at the time, is to release one flare as soon as possible , the landing area then being selected and an approach commenced By the time the aircraft is at about 300 feet the first flare will have drifted astern and will not be of much value, the second flare is then fired and a normal engine-off landing made by its light

Precautionary Landings Should the need arise for a landing to be made in an unlighted field at night the parachute flares can be used for selecting a field , and, if possible, for augmenting the aircraft landing lights during the approach The main landing light should be a spot light and the angle of elevation should be adjustable For the touchdown, a lamp with a wider and diffused arc is of assistance

On dark nights, when the horizon is not visible and there is no lateral reference, care should be taken by the pilot to check the lateral level of the aircraft by constant reference to the instruments during the approach If he does not do this it is easy for the aircraft to become banked without the pilot realising it

If there is no other means of checking the wind direction the pilot is obliged to use the forecast wind or the wind at time of take-off for determining the direction of his approach

SECTION V

Emergency Landings

One of the responsibilities that designers have before them in constructing a single-engined helicopter is the engine-off performance When the machine is built and flying, responsibility is transferred to the pilot insofar as he must not only try to fly the machine so that a safe engine-off approach can always be made to a suitable piece of ground, but must also be constantly on the alert so that there is not a moment's delay in reducing the collective pitch should the engine fail

However, knowing that the engine has failed is not so easy as it might at first appear The pilot may be adjusting maps or momentarily concentrating on something not directly connected with controlling the aircraft , in addition, he may have earphones over his ears, which effectively cut out a good deal of the engine noise The chances are, therefore, that the pilot will not appreciate an engine failure immediately Although there will be a swing in the yawing plane, the pilot's rudder correction will be automatically applied and his subconscious mind may associate the yawing movement with sudden turbulence acting on the aircraft It will be quite easy for the critical stage in rotor revs to be reached before a reduction in pitch is effected, with the result that the blades will cone upwards , and once a certain limit is reached there is nothing the pilot can do to save the aircraft from disaster

If, on the other hand, the pilot becomes immediately aware of his engine failing he has still to take the appropriate action The time at his disposal depends on the following factors

The type of rotor

The rotor energy, which is a function of the revs at the time of engine failure, and the moment of inertia of the blades

The pitch setting of the rotor blades at the time

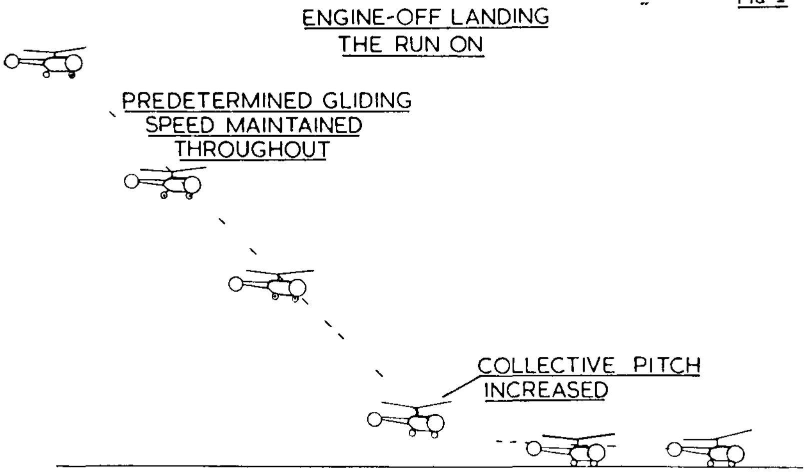
The speed of the aircraft

At the best, the time available is not much more than five seconds , at the worst, less than three When we consider that the reaction time of a skilled pilot may be two seconds following failure, we are left with a very small safety margin, especially as reaction time will vary adversely when he is tired

In the event of the pilot reducing pitch in time, he has then to select his landing area and adjust his approach In judging the approach the factors to be considered are the wind and the terrain Upon the latter will depend the type of landing to be carried out Will it be a run-on or a flare-out ?

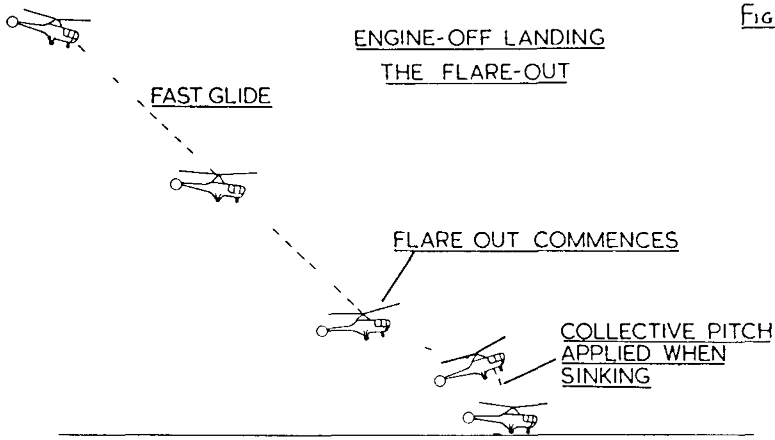
A brief description of these two types of helicopter engine-off landings is worth stating here

FIG 1



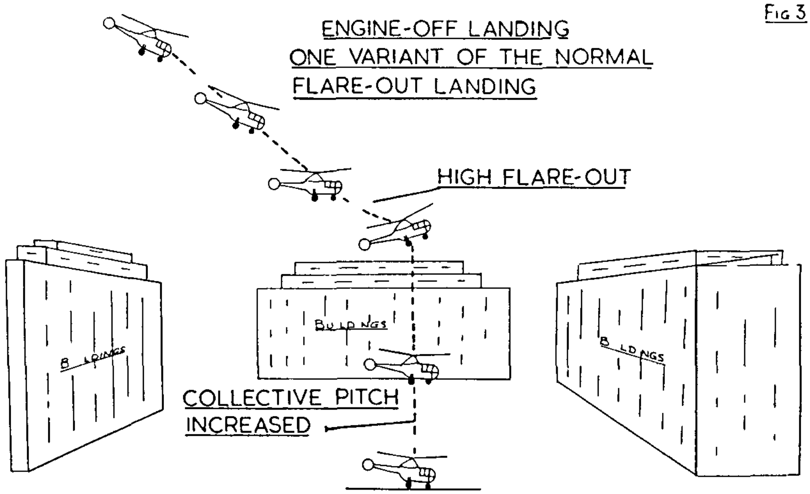
In the run-on, or as it is sometimes called, the " no flare " type of landing, (Fig 1), no effort is made to reduce forward speed for the touchdown , instead, a predetermined airspeed, which ensures that the aircraft is longitudinally level, is maintained by use of the cyclic-pitch stick The necessary decrease in downward velocity for the touchdown is accomplished solely by use of the collective-pitch lever which is gently raised when the aircraft is at a height of about ten feet, the descent of the helicopter being then nearly all arrested and a gentle final sink made on to the ground—still at the same forward speed as during the approach The collective-pitch lever is then lowered again

Fig 2



In the flare-out landing (Fig 2), the aircraft is glided at a moderate airspeed—the figure varies with different aircraft, but 50 m p h is an average figure—until at a height of about forty feet the cyclic-pitch stick is brought back and both the descent and forward speed of the aircraft are almost wholly arrested , at the same time the rotor revs tend to increase due to the kinetic energy of the helicoper being converted into kinetic energy in the rotor system The helicopter is then practically hovering and has its tail down at a well defined angle As the aircraft starts to sink from this position,

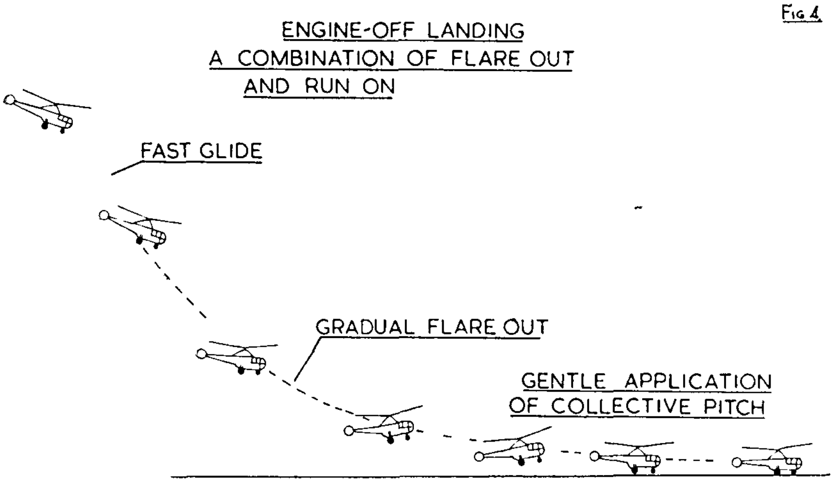
Fig 3



the cyclic-pitch stick is pushed forward again in order to return the fuselage to a level attitude Just before touching down, the collective pitch is increased to provide the cushioning effect necessary for a reasonably gentle touch-down On landing, the collective-pitch lever is again put down to the lowest position so as to reduce the possibility of the aircraft rolling over

These are the descriptions of the pure and simple versions of the run-on and flare types of engine-off landings But there are hundreds of possible variations of them, either singly or combined For instance, one could carry out a very high flare followed by a long vertical descent between houses with a very sharp application of collective-pitch upon arriving in the High Street (Fig 3) Or, a very gradual flare can be made close to the earth followed by a gentle lowering of the aircraft on to the ground at about 20 m p h with the aid of the collective-pitch lever (Fig 4) In this case, however, there is a very real danger of striking the tail rotor on the ground with present helicopters An alternative to this last type of landing is one in which the collective-pitch lever need not be used at all and a normal aeroplane landing is made, but this is only practical in a helicopter that has a low sinking speed in autorotation, and whose tail rotor, if it has one, is positioned high

FIG 4



To revert to the question of which type of landing the pilot will use Nine times out of ten the flare-out type will be selected, for large flat surfaces are not common over the countryside, and even if a flat field does happen to be below, it may be so soft that the wheels might dig in and overturn the aircraft

Run-on landings have the advantage of a more controlled final sink to earth in the last stages, and also that extra energy, in the form of fuselage inertia, is available for conversion into rotor energy up to almost the last moment should the need arise owing to a misjudged approach They have the disadvantage of a fast forward motion relative to the earth when touching down with the consequent possibility of more severe damage in the event of a bad landing

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Flare out landings are safer because the forward speed of the aircraft is practically nil during the final arrival on the ground, and even a comparatively bad landing is unlikely to damage the occupants although the aircraft might suffer

The main difficulty in performing a flare out landing is judging the height at which to execute the flare If it is carried out too high, the pilot is left semi-hovering in mid air with the valuable extra revs gained during the flare gradually dropping back to normal while the aircraft is rapidly sinking to earth If on the other hand he flares out too low he is in danger of striking the tail rotor on the ground with possible disastrous results

Following the actual flare, the next trial of the pilot's judgment is the application of collective-pitch Broadly speaking, the pitch lever can be pulled up only once If pitch is increased when the aircraft is still too high, all effective revs, are lost and the aircraft will settle heavily on to the ground

If the increase in collective-pitch is applied when the aircraft is too near the ground and sinking fast, then the increase in rotor thrust will come too late to prevent a heavy arrival

In the past, helicopters have suffered from not having enough rotor inertia available to the pilot, and it has required precise judgment to determine the exact moment at which to increase the collective-pitch

What of the future ?

Engine failure in a single-engined helicopter today requires an action on the part of the pilot that no doubt will be considered crude in the extreme to the helicopter operators of the future Few people would fly in a single-engined fixed-wing aircraft if they knew that should the engine fail the wings would come off were the pilot not to take a certain swift action Yet they will blithely fly round in a helicopter, which could suffer the same sort of fate, thereby showing either a great ignorance—or perhaps a great faith in the pilot At present, too much depends on the pilot's immediate re-action in the event of engine failure for helicopters to be considered safe for a private flyer of limited air experience to fly about the sky Until the emphasis is on making helicopters safer, and not on higher and higher payloads, the piloting of the single-engined machine must be left to the professional pilot

What does the pilot require in the helicopter to make it a safer machine than it is now in the event of engine failure ? In answering this, one must tread on some well-worn ground but the points are worth reiterating, and it is gratifying to pilots to note that many of them have already received attention in the design of some British helicopters

Firstly, if helicopters cannot be designed so that the blades are always within the autorotative pitch-range, then there must be some kind of automatic pitch-reduction device which will prevent blade-stalling in the event of engine failure Whether this should operate following a drop in rotor revs or following a dangerous increase in coning angle is up to the designers The device should function as a kind of constant-speed device after it has started to come into operation, so that although it prevents the rotor revs dropping off it also does not allow dangerous over-speeding of the rotor should the aircraft happen to be flying fast at the time of failure

This device must, of course, have a manual cut-out system so that it is inoperative when the helicopter is hovering close to the ground In this case the pilot's reaction in the event of engine failure is to *increase* collective pitch, either immediately, or a split second after lowering the lever

Secondly, the blades must have a high moment of inertia Coupled to this is the desirability of having a wide range of revs so that a combination of the two—high inertia blades plus extra revs in autorotation—will enable several seconds hovering to be possible following an engine-off approach, by using the extra kinetic energy stored in the blades

Thirdly, some sort of warning device must be fitted so that the pilot is immediately aware of any power loss and the automatic reduction in pitch, and can gain valuable seconds for adjusting his flight path and choosing his landing field A reasonable type of warning device would be bright flashing lights coupled with an electric horn

These remarks apply to single-engined helicopters The ideal would be for every passenger-carrying helicopter of the future to be twin- or multi-engined, the single-engined variety being used for freight-carrying or for a certain degree of private use

SECTION VI

Pilot Comfort and the Problem of Pilot Fatigue

It is important that the pilot shall be comfortable during flight (*a*) to prevent him becoming fatigued with the consequent deterioration in efficiency, and (*b*) to allow a high pilot-utilization

There are two types of comfort physical and mental, and it is mainly physical comfort with which I deal here In most cases I attempt to offer some sort of standard which pilots think manufacturers should aim for

Controls

By far the most outstanding problem in the question of pilot comfort in helicopters is the one of controls Much of what I have to say is coupled to the section on controls

The best way of dealing with the comfort and fatigue question is to make statements of what I consider to be the ideal dimensions, stick forces, angular movements and other factors concerned with the controls Although I make generalised statements about some of these, the manufacturers will naturally have to consider the average pilot Within limits, most pilots may be catered for by the use of adjusting devices fitted to the controls and seats

The Cyclic-Pitch Stick My basis for consideration is the cruising flight condition, since this is the one which occupies most of the pilot's flying time, and I try to make it the condition for maximum comfort

In cruising flight, the part of the cyclic-pitch stick which is held in the hand should be one inch behind the pilot's knee The bottom of the fist should be level with the knee, so that the arm can be rested on the thigh

The maximum forward movement of the stick from the neutral position should not be more than seven inches , the arm is then never quite at full length and the shoulder need not be taken off the backrest The maximum backward movement depends largely upon the dimensions of the aircraft seat, and should also be of the order of seven inches The sideways movement from the neutral position should be a maximum of six inches each way

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A word about control forces The larger the aircraft, the greater the control forces usually become But I think they should be kept lighter in the cyclic-pitch stick than in the control column of an aeroplane of comparable size, by the use of powered controls if necessary It is reasonable to assume that the manoeuvrability of large helicopters will be a great deal better than a fixed-wing aircraft of the same size, so the stick forces must remain fairly light

In smaller helicopters which have an all-up weight of about 6,000 lbs , the stick forces in the trimmed cruising condition should be of the order of one pound for very small stick movements , and this figure is the one which corresponds to the force that a pilot would use if he held the stick between thumb and forefinger With a quick positive control movement out of the trimmed condition, and with the helicopter maintaining an approximately constant airspeed, the force should increase as the stick diverges to a maximum of eight pounds

The " feel " of the stick in a helicopter is different from that of a fixed-wing aircraft , this is partly due to the time-lag following a control movement and the pendular swing of the helicopter fuselage

" Feel " can be defined as the pilot's physical consciousness of a control movement and the response of the aircraft to that movement, and has nothing to do with incidental movements by the stick due to present helicopter imperfections

I am in favour of damping those feed-back forces that can occur at any stabilised speed in a single rotor helicopter, to a point where just sufficient is retained to enable the pilot to judge whether the rotor is out of track or out of balance But this near-irreversibility should not be accompanied by any marked increase in friction in the control system Among its other disadvantages, excessive friction in the control system would exclude any possibility of stick-free stability

If helicopters were stable in the stick-free condition a great deal of the fatigue which pilots suffer from would be eliminated This stability, however, should be obtained from the characteristics of the rotor and not from any system of trimmers, above all, it must not be achieved at the expense of controllability

The aim of designers should be to give their helicopters positive dynamic stick-free stability in cruising flight as soon as practicable, stability at other speeds and in hovering flight being attended to later In this way, the strain attached to cross-country flying on bumpy days would be alleviated, and blind and night-flying would be a great deal easier

A further aid, which could be used in helicopters with or without stick-free stability, would be the design and fitting of a satisfactory automatic pilot The incorporation of an automatic pilot or positive dynamic stick-free stability would not only alleviate physical strain, but also mental strain , for, although control corrections are made subconsciously, the subconscious can become tired by the constant demand upon it Incidentally, when I talk about " control corrections " I should qualify this by saying *continuous* control corrections For, except in completely calm conditions the pilot is applying pressure to the stick one way or the other every two or three seconds

Collective-Pitch Lever The arc through which the hand has to travel when moving the collective-pitch lever is an important consideration In the design like the S 51 the pilot is given as much leverage as possible in order to move the heavy jacks in the control system With the refinement of a lighter control, the designer is free to make his choice as to the length of lever and the angular movement of travel over the full range from fine pitch to the normal maximum The S 51 lever is, of course, too long and has too great an angle of travel On the other hand, the angle of travel in the Hiller 360 I find to be too small, which makes the control rather too sensitive

The lever should be as light as possible to move, and forces from the rotor should not cause it to alter its position An adjustable friction device should be incorporated so that the pilot can select the degree of lightness suitable for him, and so that there is no tendency for the lever to creep up or down due to vibration

When level with the pilot's thigh the nearest side of the lever should not be more than three inches away The arc of travel of the lever should be such that the hand is never raised above the level of the elbow and in the lowest position of the lever the arm should still be slightly bent and the pilot's shoulder should be in position against the backrest In operating the lever it should not be necessary for the body to be moved at all

Throttle Many of the requirements for the throttle have been mentioned in the previous section There is one matter, however, to which careful attention should be paid , that is the diameter of the grip in the twist-grip type A variation of a quarter of an inch in the diameter can make all the difference between the pilot's hand being comfortable and having it start to ache after some fifteen minutes intensive flying A diameter of $1\frac{3}{4}$ inches is satisfactory, but a diameter of $1\frac{1}{2}$ inches is too small

The other salient points can be summarised as follows (*a*) The throttle should be very light and positive to move, but should, like the collective-pitch lever, incorporate a friction device (*b*) Some trouble should be taken in setting the relationship of angular movement to actual change of engine r p m It is important that the throttle is not too sensitive, otherwise the pilot takes a long time to adjust his power setting and has to concentrate too much I consider 180 degrees of total movement to be just right This is the range of the one in the S 51 , in comparison, the throttle in the Bell 47B has only 45 degrees of movement and is much too sensitive

Rudder Pedals The rudder pedals should be of the type in which the whole of the foot is supported by the pedal, thus giving freedom of movement without the heel being scraped against the cockpit floor The pedals should have as large a range of adjustment as is practicable

The position of the body and legs is of the utmost importance Designers should ensure that the pilot is not sitting with his legs too high—a position which makes the back ache very easily If the rudder pedals were given a large degree of adjustment, and present tendencies are to give the pilot only a small amount, much of the trouble would be overcome and, in addition, both large and small pilots would be comfortable and enjoy full control

The setting of the rudder pedals should be such that in normal cruising flight at maximum all-up weight the pedals are level with each other There is a tendency in some helicopters to have no allowance made for the fact that at fast speed the weather-cocking effect of the long tail tends to balance the torque of the main rotor, thereby making the usual thrust of the tail rotor too great The pilot has to remove some of the thrust by applying right or left rudder, depending on the direction of rotation of the rotor, and this can become tiring

The force required to make a change of rudder pedal position should be a light one of about five pounds, and when the rudder pedal is depressed it should stay in the new position   This is contrary to fixed-wing practice in which the rudder pedal returns to a neutral position   In helicopters, the normal purpose of the rudder control in cruising flight is to make adjustment for torque-changes associated with alterations of power or aircraft speed, and not to assist in turns

Seating

Second in importance to the controls, from the point of view of pilot fatigue, is the type of seat provided for the pilot

Again I take the cruising flight condition as the one with which we should concern ourselves, for in this case the longitudinal attitude, which varies with speed, has to be considered

Since he has to sit in one position for several hours, a pilot should be made as comfortable as possible   The backrest of the seat should be tilted back at an angle of 10 degrees to the vertical , but it should be adjustable about 7 degrees either way and should be made of fairly soft material, padded leather being considered suitable   On the other hand, the seat cushion should not be of padded leather, but should be even softer, in fact something like the normal armchair cushion   The shape of cushion and seat should be such that some support is given to the thighs without preventing the pilot obtaining full and free movement of the rudder pedals

The seat should be fully adjustable for up and down movement   Will helicopter designers note that sometimes a pilot wishes to wear a parachute ? When he does so he does not want to sit with his head touching the roof, but in his normal position, so let us have pilot seats with a lower adjustment than hitherto   The seat should not be adjustable in a fore and aft direction because if it were the collective-pitch lever would be in the wrong position in relation to the hand and arm

Heating and Cooling

It is obvious that a pilot likes to be kept warm in winter and cool in summer   The cooling is reasonably straightforward to tackle in Britain The fitting of adjustable louvres solves the problem for cruising flight and a fan of some description can keep the pilot cool in hovering flight   I have no experience of operating helicopters in the tropics, but I should think that the cockpit temperature could get very high indeed and that something more drastic has to be done to keep the pilot cool, such as replacing the clear windows with colour filters, or providing removable filters to fix on the windows   These would also benefit pilots in any latitude, for an evening sun shining on the side of the face can be most dazzling and cause headaches

As regards cockpit heating, the amount of heat given out must be adjustable, and when working, the heater must not smell   Above all it must produce *enough* heat

My personal feelings in the matter are that the use of exhaust heat by a heat-exchanger is the best method for helicopters, but the pilot must be able to adjust the output of heat himself

An additional requirement for the heater is that it must keep the inside of the windscreen clear of mist and the outside clear of ice   To act as an anti-mist device the heater merely has to maintain the temperature of the cockpit air above the dewpoint and this being fairly easy to do little trouble is experienced in de-misting To keep the windscreen clear of ice plenty of heat must be used and here my previous remarks on producing enough heat again apply

Draughtproofing

Although a helicopter might be draughtproof when new, after a time various parts of the doors and windows get distorted or the rubber fittings get perished, completely counteracting the effect of the heater and causing additional discomfort To say that manufacturers should make an aircraft draughtproof sounds obvious, but there is still a lot that can be done in some aircraft and I would suggest that doors and windows are designed in such a manner that it is a simple matter to insert a new or larger piece of felt or rubber when the need arises

Noise

There are various types of noise in aircraft which can cause discomfort to the pilot Some of them, such as panels rattling and objects vibrating, apply equally well to fixed-wing aircraft as to helicopters, while noise from the rotor, which I do not consider unduly excessive or unpleasant, is applicable only to the helicopter Noise has more significance in the present rotary-wing field than it has with fixed-wing aircraft because it is important that the pilot is not fatigued and can react immediately to engine failure

There are two chief types of noise which worry the pilot noise due to the engine, and radio background noise Engine noise can be roughly divided again into two parts exhaust noise and the noise of the engine itself

Exhaust noise always tends to be loud, but the degree of discomfort from it depends on the position of the exhaust pipe in relation to the cockpit, whether the engine is high revving, whether the cockpit is efficiently insulated against sound and whether the doors and windows are open or shut

The exhaust noise problem in helicopters is already receiving some attention from manufacturers because of the annoyance which will be caused to the public when helicopters begin city centre to city centre operations If the problem is solved from the public's point of view, it will, of course, be solved from the pilot's aspect as well

In single-engined helicopters the noise from the engine itself may be more of a problem than it is in the multi-engined helicopter due to the proximity of the engine to the cockpit When the manufacturer has done his best to make the cockpit soundproof and has ensured that it is easy to maintain it in such a condition, there is nothing left for the pilot to do but block out the noise from his ears with ear plugs or helmet If he does not do this but merely tries to endure the noises from all sources, it is likely that he will suffer from buzzing or singing of the ears after flight and that in the course of time he will become deaf in the higher frequency range

When the pilot has to use radio, his personal noise-stopping devices are limited to helmet or headset Although these have to fit snugly to cut out most of the engine noise, they must also be light and comfortable and not too tight Personally I have not yet found a really comfortable headset or helmet

Radio background noise should not, of course, exist It can be caused by a faulty ignition system, insufficient suppression in the engine-driven generator, poor bonding, wear of commutator brushes in the motor generator, ageing valves, general deterioration in the set and various other things which I do not claim to understand

The noise can be absolutely maddening at times and reduce the pilot's vigilance and efficiency to a low order In addition to the suffering caused to the pilot, the sound can also effectively swamp the small amount of engine noise which he likes to hear to know that his engine is running smoothly, and it could prevent him having the maximum amount of warning of an engine failure It is not for me to suggest to engineers what they should do, but I mention the consequences arising from loud radio background noise so that they can fully appreciate the pilot's point of view

Vibration

I have heard people make some disparaging comments about the abnormal vibration apparent in helicopters, and there is plenty of room for improvement in smoothness, especially in the low frequency range which I think is the most trying one Vibration tends to make the body physically tired, but the brain also gets tired and the eyes suffer some strain There is also an added mental strain in worrying about the vibration and trying to assess whether it is worse than it should be

The solution to the vibration problem lies mainly in the design, but at present smoothness must be a secondary consideration to that of performance

View and Vision

Due to the absence of wings and other protuberances the all-round view from the helicopter is better than that of any other type of aircraft There is a tendency at present for manufacturers to use the bubble types of windows, or semi-spherical-shaped windscreens I occasionally find that the material is not optically perfect and that considerable eye-strain is caused by looking through a distorted surface

A second problem for this type of windscreen is that of keeping it clear of rain or snow The portion of the windscreen directly in front of the pilot does not free itself as well as the remainder, and the rain or snow tends to cling there and cut out the pilot's view directly ahead

Under bad visibility conditions it is very tiring to be continually moving one's head in order to see straight forward For this reason I am in favour of a flat sloping surface for the windscreen, as it can be kept clear by a normal type of wiper

Until recently, the instrument panels in helicopters did not incorporate the instruments necessary for blind flying Now that instrument flights are being undertaken there is a tendency for the panels to be increased in size to take additional necessary instruments With some thought, however, it is possible to keep the panels down to a reasonable limit by grouping only the essential instruments directly in front of the pilot and relegating the others to an inferior position In this way the excellent view, which is such a pleasant feature of the helicopter, can be retained I should like to suggest here that some of the instruments at present in use take up a lot of panel space but show very little for it in the dial For example the Direction Indicator takes up twenty square inches of panel space, but the information supplied to the pilot takes up less than one square inch Would it be possible in some cases to have the " works " of the instrument somewhere else in the aircraft and have some small form of compact repeater on the instrument panel ? If this were possible then instrument panels would remain at a reasonable size, the good view would be unimpaired and the eye-movement necessary to read the instruments as a whole would be very much reduced and therefore less fatiguing

SECTION VII

Pilot Training

Under this heading I propose to summarise the conversion of a trained fixed-wing pilot to helicopters , and then, looking ahead, give the outline of a programme for the training of a pupil, with no previous flying experience, from the *ab initio* stage of helicopter piloting to the stage when he becomes fully operational

Firstly then

Present-day Pilot Training on Helicopters

Qualifications

Education and Physical Category No operator in this country is, as yet, considering the training of pilots other than those who have already gained fixed-wing experience Accordingly, education and physical categories need not be considered in this case, for it must be assumed that fixed-wing pilots already possess the necessary standards required

Previous Flying Experience In flying circles a lot of nonsense is talked about flying hours It is often considered that a man with, say, 1,000 hours, has twice as much experience as a man with 500 However, the only criterion should be what the pilot has actually done with his hours Half of a pilot's 1,000 hours in his log book may have been spent asleep in the back of a Coastal Command aircraft, while much of the remainder may have been passed in keeping an eye on an automatic pilot The 500 hour man on the other hand may possibly have spent every single hour at the controls and used his hours instructing or in operations requiring high personal flying skill and initiative There should be no question as to who is the better qualified for any piloting job

In selecting pilots for conversion to helicopters, therefore, no hard and fast rules should be laid down as regards the previous number of flying hours for giving preference to one or other pilot A certain minimum must have been obtained, but after that keenness, character, flying ability, suitability for the job, and, if necessary, the holding of certain licences should be the considerations

Helicopter Conversion Instruction

Primary Training

Aircraft The ideal training aircraft must incorporate the following design features

(*a*) It must have a single engine and a single main-rotor

(*b*) It must be light to handle so that pupils will not tire easily and delay training

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(*c*) It must require a fair degree of skill to fly with precision, but at the same time it must be possible to fly with the lower degree of skill that a pupil must be assumed to have initially The general characteristics should be such that a pupil would know when he was flying with any lack of precision

(*d*) The general stability of the machine should be such that it is equivalent, or slightly inferior to, the operational machines of the time By this I mean that if even one operational machine at the time showed a marked lack of stability then the primary trainer should also have this characteristic

(*e*) It must have side-by-side seating with full dual controls

(*f*) It must have two collective-pitch levers and not just a single one in the centre

(*g*) It must have flying qualities which allow complete engine-off autorotation flare-outs and landings to be made

(*h*) It must have a harsh undercarriage so that precision is required to make a good landing

(*i*) It must have a robust undercarriage so as to permit engine-off landings to be carried out frequently and safely

(*j*) It must have means of preventing damage to the tail rotor (if it possesses one) in the event of a flare-out being executed too low This can be done either by setting the tail rotor high, or by providing some form of efficient guard for it If it is set high, however, care must be taken to ensure that it does not have the effect of producing a sideways tilt of the fuselage in hovering flight

(*k*) Economy being important, the aircraft should be fairly small, weighing about 2,000 lbs all up

(*l*) The basic instruments should be augmented by a *sensitive* altimeter and a rate-of-climb indicator

(*m*) The engine should be of such power that it *is* possible when hovering to overpitch the rotor blades when the aircraft is near its full weight and when there is no wind

The last point is important because complete understanding of the consequences of under-revving or over-pitching is a fundamental helicopter piloting feature and unless it is possible for pupils to be fully instructed on that point accidents are bound to happen later on

Flying Instruction Instructors have their own particular methods, and the following schedule of actual exercises to be practised is for guidance only It is based on present-day aircraft and not on the ideal aircraft just mentioned The order of these exercises need not be followed strictly, for much depends on the progress and temperament of individual pupils

Naturally, the exercises do not necessarily have to be carried out completely satisfactorily before the next one is commenced The newer exercise may help the previous one , for example, in practising the autorotation sequence part of the circuit pattern is introduced

It should be emphasised that while the pupil is carrying out his flying training, the ground instruction mentioned later on should keep pace, step by step with it

SCHEDULE OF FLYING INSTRUCTION FOR HELICOPTER CONVERSION COURSE

1 Cyclic-pitch stick and rudder pedals in straight and level flight
2 Cyclic-pitch stick and rudder pedals in medium turns
3 Cyclic-pitch stick and rudder pedals at various air speeds, climbs and descents
4 Cyclic-pitch stick and rudder pedals in hovering
5 Collective-pitch lever only, in hovering and " up and downs "
6 All controls except throttle in hovering and " up and downs "
7 Throttle only, ground exercise
8 Throttle only, hovering and " up and downs "
9 Effect of rudder when hovering
10 All controls hovering
11 Medium turns
12 Climbs and descents
13 Climbing and descending turns
14 Engine and rotor starting and stopping
15 Full pre-flight inspection and cockpit check
16 Landings and take-offs
17 Flying backwards
18 Flying sideways
19 Overpitching
20 Transitions
21 Circuits
22 Action in event of fire
23 Entry into autorotation
24 Overshoot procedure from practice autorotation approaches
25 Turns in autorotation
26 Flare outs (with engine)
27 Throttle cutting and complete forced landing procedure
28 Pre-solo check
29 Solo
30 (*a*) Squares , (*b*) Squares maintaining a compass heading
31 Taxying
32 Anti-torque control testing
33 Steep turns
34 Tracking (Ground exercise)
35 Cross-wind hovering, take-offs, and landings
36 360° turns
37 Limited-power take-offs and landings
38 (*a*) Run-on landings , (*b*) Run-on landings without engine
39 Quick stops
40 Jump take-offs
41 Cross-country
42 Advanced approaches, steep and slow, fast and low
43 Flying in alternative cockpit
44 Flying with C G at limits
45 Flying with aircraft at maximum weight

Two most important exercises as regards safety before the pupil goes solo are over-pitching, and the auto-rotation sequence The pupil must demonstrate his ability to over-pitch and to apply the correction , and not only must he execute satisfactory flares, but there must be no doubt in the instructor's mind that the pupil will react to engine failure by instantly reducing the collective-pitch This must be practised time and time again by the instructor actually cutting the throttle in the air and leaving the pupil to reduce pitch and make an autorotation approach and flare out by himself, the engine being brought on at the last moment if the type of aircraft used for training demands it in the interests of safety I find that the time spent on forced landing practices with pupils amounts to between one and a half to two hours Dual instruction before going solo is in the region of six hours, but the actual number of hours is of small interest because it bears little or no relation to the subsequent ability of the pupil after twenty hours total helicopter flying

Some people express the opinion that six hours dual prior to solo is too much and that the pupil becomes despondent by this time They say that time spent on autorotations should be reduced I disagree, forced-landing practice might be a matter of life or death and it should not be cut down On the other hand there is no objection to the pupil being sent solo prior to forced-landing practice so long as he is not allowed to fly more than twenty feet away from the ground

During training, and especially before going solo, it is important for a pupil to fly in calm weather conditions when there is, of course, no translational lift to aid hovering, as well as in strong wind conditions   I have had pupils for refresher courses whose previous helicopter experience was limited to about fifteen hours and which was entirely carried out in conditions of strong wind   Consequently a proper appreciation of over-pitching and its dangers had not been instilled into them, the first thing they would do on a calm day was to pull up the collective-pitch lever too high and then appear not the least concerned when the revs rapidly dropped off

Fixed-wing pilots have little difficulty in handling the cyclic-pitch stick and rudder in forward flight, they usually have a lot of trouble in learning to hover and in co-ordinating the collective-pitch lever and throttle   The first few periods spent with the collective-pitch and throttle should not be too long, for initially it is a great mental strain concentrating on keeping revs at a certain figure while trying to hover as well , over-long periods can be a waste of time

When the pupil is reasonably competent with all the controls he can be put on to one or two exercises for improving his co-ordination   One of the best of these is an exercise which, for want of a better name, is called " transitions "   This not only improves the co-ordination but also effectively demonstrates the effect of loss or gain in translational lift with varying airspeeds   Described briefly, it consists of hovering at about twenty feet, gradually moving forward to sixty miles per hour without loss or gain in height and then slowing down again to the hover, also without loss or gain in height

Progress after going solo is usually straightforward and there is nothing I wish to discuss here   All the exercises, including cross-country flying, should be completed in about twenty hours total flying at which time the pupil may be licensed for aerial work   Thereafter it is up to the pupil, with the aid of occasional checks from an instructor, to call upon his past experience and use his present practice to bring himself up to a polished standard   At the completion of fifty hours as pilot in charge, the converted fixed-wing pilot may be fully licensed for the type of helicopter he has been flying

Operational Flying Training

Aircraft   It is disappointing that at present we have no large helicopters in production   The primary helicopter trainer used for conversion courses is often the actual type of aircraft which is later flown operationally

Present operational aircraft have an all-up weight of under 6,000 lbs and carry a pay-load of under 1,000 lbs   Future operational aircraft will be mentioned later in this section

Schedule for Operational Training

Assuming that the pupil has carried out primary training in the small aircraft, the suggested operational training schedule for the bigger helicopter is as follows

SCHEDULE

		Approximate Number of hours spent on exercise
(1)	Familiarization dual and solo flying to a standard where this aircraft can be added to the existing licence	10
(2)	Landing and taking-off from awkward sites	2
(3)	Weight lifting with hoist and sling	2
(4)	Landing and taking-off with floats from water and mud flats	4
(5)	If not in possession of an R/T Licence a course should be taken and the licence obtained	
(6)	Day solo cross-countries using radio aids	6
(7)	Refresher course of link training if pupil has not had recent instrument-flying practice	(10)
(8)	Blind flying in the helicopter (under the hood, etc) with an instructor	5
(9)	Solo cloud flying	3
(10)	Contact night circuits	
	(*a*) Using ground lighting	4
	(*b*) Using aircraft lighting only	1
(11)	Night emergency procedures and practice, *i e* , practice auto-rotations by the light of parachute flares	3
(12)	Bling flying at night	3
(13)	Contact night cross countries	3
(14)	Blind night cross-countries	4
	Air Hours	50

Ground Instruction for Helicopter Conversion Courses

While the pupil is undergoing air training he should receive ground instruction on various subjects Up to the time of his first solo and apart from informal discussions on the pupil's handling of the aircraft, it should consist of the following

(1) *History of Rotating Wings* In this case the Helicopter Association Bulletin of March, 1947, containing Captain Liptrot's Lecture can be taken as a good standard reference

(2) *Elementary Theory I* The syllabus should cover the following basic rotary-wing features

Function of the rotors and how fuselage movement in any direction is obtained

Unequal lift on advancing and retreating blades and methods of overcoming the problem in practical gyroplanes and helicopters

Torque reaction and the way it is balanced

Coning of rotor blades

Differences between gyroplane and helicopter

Definition of flapping and dragging

Function of drag dampers

Ground resonance

Ground effect

(3) *Elementary Particulars of Primary Aircraft* The syllabus should cover the following

Control systems
Fuel and oil systems
Electrical system
Minimum rotor revs
  engine temperatures and pressures
Maximum revs at run up
  magneto rev drop allowed
  engine temperatures and pressures
  aircraft gross weight
  rotor revs in autorotation
Causes of vibration
Desirable revs in autorotation
Safety altitude and speed
Rough air procedures
C G position, and loading
Airspeeds for normal manoeuvres
Pre-flight check
Emergency procedures
Transmission system
Speed limitations
Flight limitations

It is useful to the pupil if he can be given a written pamphlet covering the complete checks and procedure up to the time of take-off

On completion of the instruction, and prior to flying solo the pupil should be given a pre-solo exam Examples of some of the questions given are

"What is the first thing to do in the event of the engine failing?"

"Explain the meaning of ground effect"

"What is the maximum allowable mag drop?"

"What is the minimum altitude from which a safe engine-off landing can be made when flying downwind?"

After the pupil has flown solo, time can be spent in instruction of a slightly more advanced nature as follows

(4) *Elementary Theory II*

Complete elementary theory of autorotation
Difficulties associated with rotors which tilt independently of the drive shaft
Definitions of Moments, Couples, Disc Loading, etc
Gyroscopic precession
Factors limiting top speeds of helicopters
Tail rotor transitional effect and its correction

Some examples of the type of questions given for the examination on these subjects are

"Show by means of a simple diagram the various forces acting on an autorotating blade and (*b*) draw a plan view of the rotor disc and indicate the portion of the disc that obtains energy from the air and that which expends energy on the air"

"Gyroscopic precession causes a displacement of how many degrees in the direction of rotation from where the force is applied?"

(5) *Sufficient instruction of the component parts of the primary helicopter to pass the A R B technical examination for a Commercial Licence*

Future Commercial Pilot Training on Helicopters

Before going on to discuss the practical stage of *ab initio* training on helicopters, it is worth reviewing the respective differences between an *ab initio* pupil—and in this Paper I allude specifically to a man who has had no previous training in anything to do with aviation—and an experienced fixed-wing pilot who is undergoing a conversion course

The fixed-wing pilot has something which the *ab initio* pupil will take a long time to gain He has air sense

Air sense has been defined as " The achievement of a state of proficiency resulting from an extensive contact with the equipment used and the element in which it operates "

Adapting the significance of this to our own use, we can observe that the fixed-wing pilot has gained a well-established knowledge of approach angles, circuit procedure, acceleration forces to be expected in various manoeuvres, instrument interpretation, engine handling, and night and blind-flying, while he has the almost automatic ability to move the stick and rudder pedals in the correct direction In addition to this he has, on the theoretical side, a wide and practical knowledge of navigation, signals, theory of flight, meteorology, and Aviation Law

These advantages far outweigh the slight disadvantages the fixed-wing pilot may have as regards some of the habits he has had ingrained into him during his time on aeroplanes Some of the main differences he will encounter in the helicopter are as follows

(1) The throttle is not closed when the aircraft is descending, but is used to maintain constant revs

(2) When maintaining a constant heading, the rudder-pedal position is not necessarily a neutral one

(3) The helicopter angle of approach for landing is a steeper one than that of the aeroplane, and when over-shooting it is not always necessary to go round again, but merely to reduce the airspeed

(4) It is possible to reduce airspeed down to zero in the helicopter without the loss of both control and lift which occurs in the aeroplane

Let us turn now to the selection of *ab initio* pilots for helicopters

Qualifications

Educational and Physical Category I do not believe there should be any difference in qualifications between the intending fixed-wing pilot and the intending helicopter pilot

Instruction

Stage 1 It is usual for *ab initio* pilots to undergo several weeks' ground instruction prior to their training in the air At this stage of the training I feel that pilots of both categories should be on an equal standing and that they could attend classes together without any unprofitable instruction being given to either

Stage 2 *Air* Following the basic ground course, the pupil then commences his air training in a helicopter

The syllabus for the conversion course mentioned previously can be taken as a pattern, but it will naturally be modified to fall in line with the characteristics of the aircraft that will be used in the future for this work If the future training aircraft is based on the type of trainer mentioned previously, there will, for example, be no need for run-on landings to be taught Every autorotational landing could be of the type which utilises the kinetic energy stored in the rotor blades

The time spent on many of the exercises is likely to be increased considerably over the time the fixed-wing pilot takes for his conversion course For instance, the first exercises of flying with only the stick and rudder pedals are likely to occupy a great deal longer than the few minutes the fixed-wing pilot would take

I believe that the amount of dual instruction an *ab initio* pupil would need before his first solo would average around ten hours However, if necessary, individual pupils could be sent solo prior to this on a stay-close-to-the-ground basis

When he has forty flying hours, half of which should be solo flying time, the pupil should be qualified for a Private Pilot's Licence

Ground Following the preliminary instruction received in stage 1, the ground instruction in stage 2 should be of such a nature that, together with the ground instruction received in stage 3, the pupil will attain the standard required for the Commercial Pilot's Licence The knowledge required should be of the same basic character as that which is required for fixed-wing aircraft , but, in addition the History of Rotary Wings and, of course, Elementary Theory I and II, which I mentioned previously, should be included

Link Training Before commencing stage 3 of his training, the pupil should have at least ten hours blind-flying practice in the link trainer If a helicopter link trainer is not developed by this time, then the fixed-wing type of trainer should be used

Stage 3 *Air* On completing stage 2 of his training on the primary aircraft, the pupil should then advance to a bigger aircraft

It would be an advantage, but is not considered essential, for the pupil to have some experience, say 50 hours flying, on an intermediate helicopter of the 6,000 lbs all-up weight class Failing this, the pupil should go straight on to the aircraft which he will later use operationally At present this is envisaged as being a twin-engined twin-rotor helicopter of about 11,000 lbs all-up-weight But later ones will be bigger still , and looking even further ahead we shall have convertible aircraft, which will no doubt produce some interesting problems in the question of pilot training

The schedule for operational training is on the same lines as the one for the fixed-wing conversion course, and before completing stage 3, a further 160 hours should have been added, of which 130 hours should be solo flying

SCHEDULE FOR OPERATIONAL TRAINING

	Schedule	*Approximate* Hours Dual	Hours Solo
(1)	Familiarization flying to a standard where this aircraft can be added to the existing licence	5	10
(2)	Landing and taking off from awkward sites	½	3
(3)	Weight-lifting with hoist and sling	½	2
(4)	Landing and taking off from water and mud-flats with floats	1	4
(5)	R/T course for obtaining R/T licence		
(6)	Day solo cross-countries using radio aids		10
(7)	Link Training course		(20)
(8)	Blind flying in the helicopter (under the hood, etc) with an instructor	10	
(9)	Solo cloud flying		5
(10)	Cross-country Blind flying (under the hood, etc) with an instructor	3	
(11)	Contact night circuits		
	(*a*) Using ground lighting	1	3
	(*b*) Using aircraft lighting only	½	½
(12)	Night emergency procedures and practice, *i e* , practice autorotations by the light of parachute flares	½	2
(13)	Blind flying at night	½	3
(14)	Contact night cross-countries	1	3
(15)	Blind night cross-countries		3
		23½	48½
	Total dual and solo air hours		72

The remainder of the 160 air hours can be spent in revision, general flying practice, and any exercises in which the pupil may be below standard

Link Training The further twenty hours' Link Training should be of such a nature that it is complementary to the actual blind flying done in the air

Ground The ground instruction should carry on from stage 2 and complete the syllabus for the Commercial Pilot's Licence

On completing stage 3, the pupil will have a total of 200 helicopter flying hours of which at least 150 will be solo time On gaining his Commercial Licence he is then qualified to carry out commercial operations on a fairly wide scale If the future licensing of helicopter pilots is treated on a separate basis to that of fixed-wing pilots, it is possible that the Commercial Licence, plus the Instrument Rating, will be the highest possible requirement for helicopter pilots and that their scope of permitted operations will be as wide as the Airline Transport Licensee in the Aeroplane Class

Acknowledgements

In conclusion, I should like to express my thanks to those people, both inside and outside B E A , who readily gave their co-operation and help and who made many useful comments during the preparation of this Paper In particular I should like to thank Mr Washer for doing the drawings

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DISCUSSION

Mr F O'Hara, in a written contribution, which was read on his behalf by the Chairman, stated —

There will be general agreement that an improvement in stability is required to enable the operating possibilities of helicopters to be fully utilised in all weather conditions There have been reports from the United States of definite improvements on certain helicopters, such as the Hiller 360 , it would be of interest if Mr Fay could, from his short experience on this helicopter, express an opinion on its handling characteristics In particular how do pilots assess it from the point of view of instrument flying ?

The importance of providing suitable flying instruments, especially for low speed operation, is also rightly emphasised The logic of turning to the rotor disc for more exact information on the helicopter flight state is apparent, and much might be gained by the use of rotor disc attitude, and possibly, of airspeed, determined as the difference of the rotor tip speeds Even the rotor disc attitude, however, tells one practically nothing of the flight path, and this is a quantity which it does not appear easy to measure

Improvements in stability and in flying instruments appear likely to be of particularly great assistance in steep landing approaches A difficulty which could still remain, however, and restrict the maximum approach angles, is the control disturbance possible in powered descent, with the rotor operating in the vortex ring condition

On the subject of vibrations, I do not think the statement that " Smoothness must be secondary at present to performance " can pass without qualification Reduction of vibration might in fact justify some sacrifice of performance

Mr C T D Hosegood (*Founder Member*), first congratulated Captain Fay on having tackled a very difficult problem remarkably well

He had some remarks to make about Captain Fay's discussion concerning whether the pitch lever should be held in the right or left hand Some time ago it was decided that the collective-pitch lever should be operated with the left hand, the right hand being thus freed to operate the cyclic-pitch control But there were two schools of thought at the time , he belonged to the school which had lost, and he still believed there was a great deal to be said for so designing the aircraft that the pilot had his left hand on the cyclic-pitch control and used his right hand for the collective-pitch lever He had tabulated quite a lot of reasons for that, whereas he had never been able to find any solid and sound reasons for arranging things the other way round, other than that it was conventional in fixed-wing aircraft to operate the throttle with the left hand and the control column with the right

However, purely from the flying point of view, he did not believe it made any difference whether one flew with the left hand or the right hand on the cyclic-pitch control , rather was it a matter of the lay-out to which one was accustomed Since 1944 he had been changing backwards and forwards, and he was most comfortable in the position in which he had done most flying recently, for 30 or 40 hours , if he changed over, then he was uncomfortable for the first hour or so In other words, it was important that there should be some sort of standardisation , but he would like to have the collective-pitch lever in the right hand and the cyclic-pitch control in the left

Perhaps the main reasons for taking that view were that in very nearly all present-day helicopters the seating arrangement was side-by-side , and even if the helicopter were designed for full dual control, it was not really practical to have two sets of trimmers If there were not two sets of trimmers, the trimming must be done from the centre of the machine It was established, he believed—and he quite agreed with it, as everyone would probably agree—that the first pilot should occupy the left-hand seat, and that meant that with the present arrangement the pilot must change hands to trim the aircraft , there were no two ways about it As helicopters became bigger, their trimming would become more and more important, and he felt that in regard to some of the bigger aircraft that were coming along we were barking up the wrong tree by insisting that the pilot continued to fly the machine with the left hand collective-pitch lever

Another reason for using the right-hand collective-pitch lever was that, on an average trip, for 99 or even 99 9 per cent of the time the pilot had his hand on the cyclic-pitch control, whereas a good deal less than 50 per cent of the time of an ordinary scheduled flight was devoted to collective-pitch movement , once the helicopter got going on the journey the pilot could to all intents and purposes forget the collective-pitch lever, whereas he could never really leave the cyclic-pitch control Thus, with the right-hand collective-pitch lever, the right hand was free during the greater part of the flight to do the numerous jobs that had to be done, such as closing a window, folding a map, writing, scratching and blowing one's nose, and so on In the event of engine failure, when the time factor—before decreasing the collective-pitch—is critical it seemed to be a much better proposition to be able to use the right hand for the pitch lever, there being no question of changing hands, as he believed would occur if engine failure occurred when the pilot was making a note, and, therefore flying the machine with his left hand on the cyclic-pitch control

Following from that, there came to his mind the possibility that if a machine were designed with a central pitch lever we should not require two of them That was really a matter for the customer , but it would save money and weight, and it would be simpler

It would be interesting to hear anything that could be said against this layout he had advocated, but he urged that the right hand should be given greatest freedom and though he personally was very right handed he found no trouble in controlling the cyclic-pitch with his left hand

Mr C A Richardson (*Sperry Gyroscope Co*), joined in the expressions of congratulation to Captain Fay on a most interesting paper, and said that the statements he had made from the pilot's point of view would help quite a lot in the solution of many problems

Early in the paper, he continued, Captain Fay had brought in the bogey of yawing of helicopters during normal cross-country flying, but had he any practical proof that yawing did occur? One knew that helicopters could yaw, but did they in fact? Some two years ago Mr Richardson had been concerned with some extensive flying of helicopters, but in the course of these tests there was no proof whatsoever that, if the normal cruising speed were maintained, the helicopter would tend to yaw, any more than would the light aeroplane After all, using D R navigation it was best to maintain the normal cruising speed He felt that D R navigation should be quite possible in the helicopter, because we should be able to obtain very accurate Met information, in view of the low height of flight and the short range He asked whether Captain Fay had made flights purely on D R, without reference to the ground or radio

With regard to instrument lay-out as illustrated, it was very difficult to appreciate how one could fly very accurately when an eye movement of something like 2-ft was necessary in reading the instruments Mr Richardson suggested that Captain Fay should consider the ordinary gyro magnetic compass used in aircraft nowadays, in place of the Directional Gyro and magnetic compass, to avoid that considerable eye movement in maintaining course

Noting that in connection with the emergency landing method there was always a call for a fast glide, Mr Richardson asked what was the forward speed during the fast glide, because it seemed, at any rate in the case of the single-engined helicopter, that the normal approach should be something akin to the emergency approach, so that in the event of engine failure the machine could still land safely

Mr G A Ford (*Founder Member*), complimented Captain Fay on an excellent paper, to which he had obviously devoted a great deal of thought and research In the main, Mr Ford agreed with him, but he put forward his own views on several points

His only recollection of a sensitive yawmeter in flight was of one with a needle which shot from one side to the other at high speed, possibly it had been improved since, but if that were not so and if a yawmeter had to be fitted, he asked that the indicator needle should have a similar movement and sensitivity to that of (say) the bottom needle of the Reid and Sigrist Turn and Bank Indicator, so that we should know that it was dead accurate when indicating no yaw One was not too particular that it should indicate the exact amount of yaw, so long as one knew the direction of yaw and was able to apply sufficient correction to put the needle back to the middle again

Suggesting that Captain Fay was under-estimating the speed of his own reaction to engine failure, and also that of the majority of pilots, he said that surely throughout a flight, at least, the pilot's subconscious mind was standing by for a change of engine note, and we must remember that a complete and instantaneous engine failure was far less likely than a partial or gradual one, and the instrument indications often provided a forewarning

However, he fully agreed that the rotor speed range should be as wide as possible, so that the chance of the rotor folding up, following slow reaction to sudden and complete engine failure, was roughly the same as the chance of a fixed-wing aircraft going into a spin under the same conditions Concerning the suggested warning devices of flashing lights and an electric horn, he was prepared to bet that the average pilot's reaction following an engine failure would not give the hooting and flashing time to awaken his slumbering passengers, although there was no doubt that the resulting deviation from the flight path would do so !

It was stated in the paper that it was natural to hold the cyclic control in the right hand, and Mr Hosegood had urged that it should be in the left hand But quite a number of fixed-wing aircraft flying today, of all types, single and twin, had a central throttle box, so that the Captain or pupil flew with the left hand and the second pilot or instructor sat on the right and used the right hand That was done with very little difficulty, and the change-over from one side to the other could become quite automatic If the left hand could master the control column easily, so the right hand could learn quickly to cope with the pitch and throttle Therefore, in a small helicopter a single central pitch lever was quite adequate, provided, of course, that it was equally accessible to both pilots , and he considered that the inconvenience to the pilots when changing seats was far less than would be caused to the designers in providing two pitch sticks, and more especially to the man who watched the empty weight rise like a meteorological balloon

Finally, with reference to Captain Fay's remarks on previous flying experience, Mr Ford quoted the Fleet Air Arm navigator's famous instruction to his pilot, " Take your hat off , according to me we are in St Paul's Cathedral "

Mr A H Yates (*Member*), commenting on Captain Fay's view that a more sensitive rate-of-climb indicator was needed, said he had not yet seen a helicopter fitted with the rate-of-climb indicator that was used by gliding pilots, which gave a quite respectable deflection of the needle for 6 inches per second Therefore, he suggested that those indicators might be fitted in some of the helicopters in order to ascertain whether they helped the pilots There was a British type, made by Messrs Cobb-Slater, in which a green ball rose when the helicopter was rising and a red ball when sinking There was an even better German type which was fitted to German gliders and to some other aircraft, but it was not made in this country It was so sensitive that, if the aircraft were standing in the hangar and someone opened the door at the end, the needle deflected

The pilots of fixed-wing aircraft had always found much difficulty in understanding the terms " side slip indicator " and " bank indicator " The so-called " turn and bank indicator " or " turn and slip indicator " did not in general indicate bank, or slip It seemed that the training of helicopter pilots would become even more tricky unless they understood the difference between the two measurements The ordinary ball in the tube did not indicate side slip, and Mr Yates suggested that, if the helicopter pilot wanted an indication of side slip, he would have to use an indicator of the vane type

On the point that Captain Fay had found the response of the Bristol 171 to be more rapid than that of the S 51, Mr Yates asked if that were due purely to the difference of inertia of the blades, for he believed they had much the same control systems

Mr Colin Cooper (*Associate Member*), commenting on Mr Hosegoods' concern at not being able to relinquish his hold on the cyclic stick in order to free his right hand for writing notes or trimming the aircraft, pointed out that the solution was not to rearrange the position of the controls but rather to aim an inherently stable helicopter that would maintain its attitude while the cyclic stick was left unattended for periods of sufficient length to permit the pilot to make notes, etc Mr Cooper said that there was one helicopter in the United States that was actually licensed by the CAA as being inherently stable and that it was to be hoped that future British designs would have such commendable features Further, if a trimming device were incorporated in the cyclic control stick the pilot could make adjustments with the left hand without relinquishing his hold on the cyclic stick with his right hand An overhead cyclic control not only made this trimming system practical, but in Mr Cooper's opinion greatly simplified control systems in general

Mr N E Rowe (*Member*), said the Association was extremely fortunate in having presented to it what he regarded as a major statement on helicopter flying, dealt with in so satisfactory a manner The lecturer seemed to have covered the whole ground, and one was surprised that there had been so little dissent from some of the really major points that had been made He would probably be the first to agree that much that had been stated in the paper was flavoured by the fact that our main experience had been gained with single-engine single-rotor aircraft , the characteristics of the aircraft with multi engines and multi rotors that were to come we did not know much about, but Captain Fay had rendered real service by saying what he wanted to say from the pilot's point of view, of what exists now

Again it was surprising that the pilots who had spoken in the discussion had not referred to his comments on training, for one would have thought that those comments would have provoked some controversy or expressions of agreement, particularly the view that the *ab initio* pupil could go straight from the training machine to the type of machine he was to operate, even though it be quite a big one, with multi engines and rotors Mr Rowe considered the lecturer was right , but as a layman in the matter he would have thought there would have been other views, as in fact there were, as he had learned from discussions with a number of people If the design flying qualities and general piloting arrangements in the operational machines were such that we could do that, there was no doubt about the economy that could be effected in the training of pilots, converting from the primary to the operating machine, and having subsequent refresher courses to keep them fully trained in all the emergencies that might arise So this suggestion on advanced training was a very important matter both to designers and operators, and one would like to hear comments on it , perhaps also Captain Fay could expand his own remarks with regard to it

Captain Fay had no doubt whatever about the stability he wanted, and one felt that he was absolutely right If we had aircraft with positive dynamic longitudinal stability and good control qualities, then many of the questions on how to place the various controls, and so on, would cease to have relevance

Although Captain Fay seemed to regard an automatic pilot as being required, Mr Rowe was doubtful that we should go to that complication, having regard to the short journey times with helicopters and the weight problem Nevertheless, one would like to hear other views

The importance of reducing both noise and vibration from the point of view of the pilot had been stressed Mr Rowe had always regarded those factors as very important in all aircraft, though he had rather tended to have the comfort of the passengers in mind, and there was no doubt that we needed improvement there, both in the pilot's cockpit and in other parts of the aircraft

Finally, Mr Rowe again complimented Captain Fay on a very valuable paper

Mr J S Shapiro (*Founder Member*), adding his congratulations, said there were two ways by which to judge a paper One was whether the author was able to explain his subject and his problem, and the other was whether he could suggest something that we could do about it On both counts Captain Fay had shown that he knew what he was talking about That did not mean, however, that all his statements were necessarily acceptable without discussion

For example, it seemed that Captain Fay was under the impression that the control in yaw of a machine that had two or more main rotors, by means of differential cyclic pitch with one or two rotors, was likely to prove difficult or slow That was most decidedly not so , indeed, control in yaw was very effective, and the response was immediate and more than adequate

As to the specification for controls and the manner in which they would work, he said the author had gone a long way, but not quite far enough It was found that there could be very small forces acting the wrong way, which were most disconcerting So that a specification would have to include some statement on the *absence* of control forces in certain directions

Again, the specification should also contain some statement on the stick shake allowed He asked if Captain Fay considered that the refinement of inter-linkage of the collective-pitch lever and the rudder control was a desirable feature , that had been contemplated now and again and was the subject of some discussion

On the control response of the cyclic-pitch stick, there had been many opinions expressed as to whether or not the ordinary method of control led to too much delay Mr Shapiro felt that that was entirely a matter for a numerical specification The cyclic-pitch stick could be far too sensitive, the response too quick , that could occur on both single- and multi-rotor machines It seemed that pilots were extremely sensitive to the right degree of response, and it would be highly desirable if some sort of objective measure could be arrived at

Finally, with regard to the delay in the pilot's reaction in emergency, one would like to know how Captain Fay had arrived at the period of two seconds He had always understood it was one second, and it was extremely important that we should have some definite measure

Mr R Hafner (*Member*), welcomed CAPTAIN FAY'S most excellent paper, with most of which he agreed

Dealing first with some of the items with which he agreed, he discussed the kinetic energy in the rotor For many years he had been expounding the " high kinetic energy rotor," *i e* , a rotor with a large moment of inertia, capable of operating over a wide R P M range and thus storing readily available kinetic energy The Type 171 possessed such a rotor and, therefore, when near the ground was flown at comparatively high R P M This was, of course, not justified economically, but only from the point of view of safety This aircraft had remarkably good landing characteristics as the large kinetic energy stored in the rotor enabled the pilot, prior to touch down, to make two or three attempts at checking vertical velocity

By the use of tie-rods in rotor articulations very light controls were achieved and the arrangement gave a certain centralising effect at the control column It was not a natural feel, but it served as a datum Did CAPTAIN FAY consider that sort of centralising feature to be good enough, or did he consider it necessary to have an aerodynamic feed-back from the rotor ?

The next problem was one of stability They had not as yet been able to demonstrate with the Type 171, positive stability over the whole speed range, but only over a cruising range from about 40 to 70 m p h For very low speeds the stability problem had to be approached in a different way, and he asked what value CAPTAIN FAY attached to stability at very low speeds Here, as distinct from the cruising speed range, the power versus speed curve had a negative slope owing to the rapid change of induced flow in this range

This was an unstable characteristic At hovering as well as at cruising speed for minimum power the slope of the curve was zero Therefore he did not feel that hovering presented the most difficult state of affairs, rather did he feel that the most difficult situation for the pilot was the slow flying and the transition phase prior to hovering, when coming into an aerodrome in conditions of bad visibility

Considerable thought had been concentrated on reducing vibrations both in the airframe and in the controls One had rather missed from this paper, which otherwise contained so much valuable information, any statement as to the standard of vibration in controls at which we should aim, *i e*, a threshold of comfort

A very important controversy during the last few years concerned the position of the lift lever, which MR HOSEGOOD had discussed already so ably, and he would add only to this some arguments from the designer's point of view These were in favour of having the lift lever on the right-hand side If it were assumed that, on landing, the machine was making left-hand turns, which was accepted practice today, then obviously the pilot would have to sit on the left in order to obtain, during this manoeuvre, a good view of the landing place Statutory requirements and common sense demanded that certain ancillary controls, such as flaps, landing lights, switches, etc , must be arranged in the aircraft in such a way that they could be manipulated by the hand which operated the throttle, and in the helicopter the throttle was the lift lever It was difficult for the designer to provide a dashboard on the left, because the pilot wanted a view through that side It was natural, however, to arrange the dashboard in the middle of the aircraft or on the right-hand side of the first pilot's seat and, therefore, the collective-pitch lever would have to be on this side However, he asked for CAPTAIN FAY's recommendations on this matter, for we had to make up our minds as to where the pitch lever should be placed At present in Type 171 there was one on each side but obviously that was not the final solution

Mr Hafner finally commented on a point, on which he felt he was in profound disagreement with the lecturer, namely the provision of a device, which upon power failure decreased automatically the collective-pitch of the rotor such as to maintain constant rotor speed

Rotor pitch was not just simply a function of torque but depended on many other factors Thus for instance if there was a power failure very near the ground an increase of the pitch was always indicated irrespective of its effect on rotor speed At a height of about 200 feet the appropriate manoeuvre would be a decrease of pitch followed almost immediately by a large increase In both cases much depended on the rotor speed at the critical moment

In the event of a power failure during vertical climb at Max boost and optimum R P M (and away from obstructions) an immediate pitch reduction to the minimum appears to be the best manoeuvre provided the rotor lift remained high enough to retain a good measure of azimuth control If on the other hand a power failure occurred in level flight at maximum forward speed and rotor R P M a sudden reduction of rotor pitch may be highly dangerous In this case the aim would be to retain substantially the 1 0 g normal acceleration and to reduce simultaneously forward speed and rotor speed so that the aircraft remained within the safe flight envelope whilst the transition from power flight to autorotation took place The appropriate collective-pitch movement would be a slow approach to the autorotative condition

Obviously no simple device could do all this automatically and a complex one was liable to fail with possibly disastrous consequences It was his considered view that there was no need for such gadgets

With a high kinetic energy rotor the danger of rotor stalling was quite remote and compared with the stalling of a fixed-wing aircraft in similar circumstances In any case it was a matter for the designer to ensure that the placarded R P M range of a rotor (except for landing) was kept well above its stalling speed

Apart from these safety precautions, the rotor blade control articulation in Type 171 contained two notable features without involving mechanical complications

(*a*) The reduction in angle of lag of the blade about the drag hinge causes the reduction in blade pitch, this coupling being only a slight one at high collective-pitch settings and vanishing altogether at low settings
Thus a power failure at high collective-pitch would automatically be followed by a small, but instantaneous, reduction of pitch

(*b*) An increase in coning angle of the blade about the flapping hinge causes a small reduction in blade pitch
Thus a drop in rotor speed following a power failure and involving an increase in blade coning was automatically followed by a small reduction of pitch

These automatic reductions of blade pitch with loss of torque on the one hand and rotor R P M on the other, were too small to release the pilot from acting in an emergency, but, operating in conjunction with high rotor inertia and wide R P M range, gave him sufficient time to plan appropriate control action At the same time these automatic pitch reductions were too small to constitute an undesirable or dangerous interference in the control of the aircraft

Mr N E Rowe (*written contribution*) I would like to add some further remarks to my verbal contribution to Mr Fay's lecture

The discussion about the manipulation of the cyclic control and the collective pitch control is, I think, symptomatic of the general feeling that we must make the flying of the helicopter much simpler, and I would much value MR FAY's views on the main difficulties as they exist and his suggestions of the major steps that could be made on the simplification

Author's Replies to Discussion

In reply to Mr O'HARA, Captain Fay said that he did not wish to be too authoritative about the Hiller 360 for he had flown it only for ten minutes on a calm day He did, however, consider it the most stable helicopter he had flown and was very impressed by it The 360 also appeared to be stable when hovering hands off, although in the machine in question he had noticed a tendency of the stick to oscillate occasionally

With regard to instrument-flying in the Hiller 360, he thought it would be just as easy, if not simpler than, flying a comparable fixed-wing aircraft on instruments

In reply to MR HOSEGOOD, Captain Fay stated that many good points had been put forward in favour of the single and central collective-pitch lever It was unfortunate that we did not have present some of those people, other than himself, who represented the other school of thought MR HOSEGOOD had mentioned that complete familiarity with one type of lay-out was a point to be considered, and although this was Captain Fay's sole point in favour of a left-hand pitch lever it was a most important one

Replying to MR RICHARDSON, Captain Fay stated that helicopters did tend to yaw in flight and that this was mainly due to the fact that at forward speeds the weather-cocking effect of the tail was tending to balance the torque To rectify the excess moment produced by the tail there had to be a change of rudder-pedal position for every change of speed For proof of yawing Captain Fay had flown a helicopter fitted with a yawmeter and a ready tendency to yaw had been found He did not know the degree of yaw indicated, or whether it was more than that found in a light aeroplane, but if accurate D R navigation was required over the sea at speeds other than normal cruising, then it might be well to provide some indication to the pilot as to whether or not he was flying in a yawed condition At present, however, it was difficult for a helicopter pilot to carry out D R navigation while controlling the aircraft , in addition, the greater drift of a slower aircraft tended to reduce accuracy, especially if the forecast winds were inaccurate Radio aids were essential for normal navigational purposes when not in sight of the ground

During flight the pilot rarely looked at his compass once he had set his direction indicator, so the eye-movement was not generally as great in the S 51 as had been suggested

As regards gyro-magnetic compasses, these weighed about 14 lbs If they were used, the law would still require the installation of a direction indicator, so the weight penalty was at present too great to justify fitting a gyro-magnetic compass

The normal speed in a fast glide was 60—70 m p h in the S 51, and 50—60 m p h in the Bell 47B

In reply to MR FORD, Captain Fay said that he did not think he was under-estimating anyone's reaction to engine failure He had spoken to

Squadron Leader Cable about pilot's reaction times and apparently some tests had been carried out by the A F E E on this matter Reaction time was found to be two seconds normally, and even with much practice became only slightly less As for warning devices, a half second difference in reaction time might make all the difference between life and death

Replying to Mr YATES, Captain Fay stated that he was familiar with the rate-of-climb indicators used by glider pilots He pointed out that they, too, worked as a result of changes of air pressure and in the helicopter the readings could be influenced by rotor downdraught near the static vent

Replying to Mr ROWE, Captain Fay said he felt that so long as the weight was kept reasonably low, an automatic pilot would be a good thing to have because all helicopter flights would not necessarily be very short and an automatic pilot would lessen the pilot's fatigue and allow a higher utilisation

Replying to Mr SHAPIRO, Captain Fay said that he was interested to hear that there was no time-lag in the differential cyclic-pitch method of yawing control As regards stick oscillation he would not like to have any at all, if stick shake existed it would indicate to the pilot that something was wrong somewhere

The inter-linkage of collective-pitch and rudder control, in so far as the achievement of automatic compensation for any torque change was concerned, would be a desirable feature so long as it did not interfere with normal rudder control Among other considerations the arrival of the jet-driven rotor might cause any practical research in this matter to be a waste of time and money, for its usefulness would be short-lived

In reply to Mr HAFNER, Captain Fay stated that he did not think it possible to have any *significant* feed-back of aerodynamic forces from a rotor In his paper he had mentioned that the only feed-back forces causing a stick oscillation should be ones associated with imperfections such as the rotor being out of track He felt that Mr HAFNER's light control with a centralising device was satisfactory

Slow-speed flight would be necessary during a steep approach to a rotor-station When flying down a beam under blind-flying conditions the forward speed might become reduced to zero when correcting a slight over-shooting of the beam Stability in the lower speed-range would greatly help the pilot's exacting task

In reply to Mr ROWE's written contribution

The main difficulties of piloting a single-rotor helicopter from the point of view of a beginner can be summarised as follows

(*a*) The normal difficulties of controlling a new type of vehicle in an unfamiliar medium The helicopter has a large degree of freedom and the pilot must become accustomed to flying in any direction regardless of the aircraft heading

(*b*) Fuselage attitude can bear little relation to the flight path

(*c*) Good co-ordination is required to maintain proper control This is made extra difficult by the fact that there are four controls to co-ordinate and the controls differ in response

(*d*) The pilot must be careful to maintain the revs above the lowest permissable figure If this is not done it might be impossible to recover the revs and the aircraft will crash Exacting concentration is sometimes required to keep the revs at the correct figure (*e*) A change of power means a change of torque and the rudder-pedal position must be altered to prevent a swing of the fuselage

(*f*) If the helicopter possesses any weather-cock stability, a change of speed will necessitate a change of rudder-pedal position

(*g*) When the pilot has become used to operating the power control with his left hand and his directional control with his right, it requires considerable practice to swap over the functions of the hands, as might be necessary in a helicopter with dual control side-by-side seating and only one central collective-pitch lever

(*h*) Most helicopters are unstable, therefore constant corrective movements are required with the cyclic-pitch stick

(*i*) The helicopter has a pendular swing under the rotor, which, in association with the instability, makes control movements complex

(*j*) If the controls are heavy, the arm can quickly tire when making constant control movements

It might appear from this that only supermen can fly helicopters , but even riding a bicycle or driving a car seems difficult initially, and once sufficient practice is gained in helicopter piloting the control movements become almost automatic In fact, the trained helicopter pilot has a less exacting task than his fixed-wing brother so far as landings and take-offs are concerned In the future it is hoped that instrument flying will also be simpler

I feel that the opinions of many people with only a few hours helicopter experience have carried too much weight in the past, and analogies such as " balancing billiard balls on pins " have tended to give the wrong impression of the piloting problem In order to control any vehicle properly there can be no substitute for practice However, there *are* design features which would aid the pilot Although mentioned in my paper they do not refer directly to the general piloting problem, but rather to certain aspects of piloting The improvements listed below refer to the difficulties (*a*) to (*j*) given above

For (*a*) and (*b*) nothing can help the pilot except practice

For (*c*) and (*d*) one control could be eliminated and the revs maintained at a constant figure by incorporating a constant-speed head (See " Controls, Throttle " of the paper)

For (*e*) and (*f*) the torqueless rotor configurations using jet- or rocket-driven blades require no torque balancing systems Without a tail-rotor the alteration of torque-balancing forces with speed would not occur Alternatively the system mentioned by Mr SHAPIRO (whereby torque changes are balanced by an automatic change in the torque-balancing system) could aid the piloting problem

(*g*) International standardisation of controls should be sought

(*h*) and (*i*) Possession of stability would eliminate many of the difficulties (See " Pilot Comfort, Controls ")

(*j*) Obviously the controls should be kept reasonably light (See " Pilot Comfort, Controls ")

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SUMMING UP AND VOTE OF THANKS

Mr W STEWART (Royal Aircraft Establishment), who was invited to make a brief summing up of the proceedings and to propose a vote of thanks to CAPTAIN FAY, said that the occasion was rather unusual, in that they had been able to get a pilot out of his helicopter and to face an audience in the lecture room CAPTAIN FAY had presented a paper containing a wealth of detail, but one felt that the main point about it was the way he had shown how he had reached his conclusions He had shown why, in one type of helicopter, the measure of a certain factor was so much, and in another helicopter it was entirely different, in one case it was too much and in the other it was too little and, by a process of logical reasoning, CAPTAIN FAY had stated in quantitative terms the sort of thing we must provide Mr Stewart recommended a detailed reading of the paper, there was a wonderful wealth of detail in its recommendations

Selecting particularly the sentence from the paper which read "This may sound elementary, but it is not always done," he said that that reflected the situation which occurred so often in connection with the helicopter The operators asked for something and the designer agreed that they should have it, but they did not get it The sentence quoted applied to a number of items discussed in the paper, and Mr Stewart directed to it the attention of designers

It was indeed a pleasure to propose a most hearty vote of thanks to CAPTAIN FAY

(The vote of thanks was accorded with enthusiasm)