

## RESTRICTED

### PART 2 : SECTION 4

#### CHAPTER 12

## BASIC HELICOPTER FLYING TECHNIQUES

### Introduction

1. Control of the helicopter usually presents some difficulty to the experienced fixed-wing pilot during the initial stages of instruction. However, this initial difficulty is soon overcome and helicopter flying becomes absorbingly interesting, continually presenting new problems and new and sometimes amusing possibilities. For this reason, unless restraint is exercised until experience is gained, over-confidence in the capabilities of both the aircraft and the pilot may easily be bred; the helicopter pilot should always remember that although his aircraft is capable of a wide variety of tasks and can operate from places that are inaccessible to any other type of vehicle, he may be let down with little warning and with surprising speed if he mishandles the aircraft. If, on the other hand, the pilot is careful and uses the recommended flying techniques, the helicopter is without doubt the safest flying machine in existence.

### Control of Power and r.p.m.

2. The collective pitch lever (the lever) with its twist-grip throttle, is held in the left hand and it is the use of this control that presents the greatest difficulty to the student pilot. The function of the collective pitch lever is to control power and r.p.m., and therefore height. Its effects are as follows:—

*Raising* : increase in boost—decrease in r.p.m.

*Lowering* : decrease in boost—increase in r.p.m.

Operation of the *twist-grip throttle* produces the following effects:—

*Opening* : increase in r.p.m. and boost.

*Closing* : decrease in r.p.m. and boost.

The safe range of r.p.m. in flight is often quite small, being limited on the one hand by the maximum permissible engine speed, and on the other by the coning angle, which increases as r.p.m. fall owing to the reduction in centrifugal force. An increased coning angle reduces the effective rotor disc area, requiring increased pitch if the lift is to be kept constant; a point is

reached at which engine power is insufficient to overcome the high blade drag and the r.p.m. then start to decrease. This condition, always associated with low r.p.m., is known as *overpitching* and the control technique is designed to avoid it at all times.

3. When increasing power, therefore, the initial action must always be to first open the throttle and then raise the lever. When reducing power, however, the downward movement of the lever increases rotor r.p.m., so this movement is made first, the r.p.m. being kept constant by closing the throttle as the pitch is reduced.

4. If it is desired to change the r.p.m. while at a constant boost setting, the initial action is always taken with the throttle, but as this always affects the boost (para. 2) a lever movement is also necessary:—

*Increase r.p.m.*: open throttle, lower lever.

*Decrease r.p.m.*: close throttle, raise lever.

In the more common helicopter configuration (*i.e.* single main rotor with tail rotor), any power variation requires rudder correction owing to the change in torque.

### Control in Hovering Flight

5. In forward flight the effects of the controls on height, attitude and direction are very similar to those of fixed-wing aircraft, but their effects while hovering must be much more clearly defined.

6. The cyclic stick (the stick) tilts the rotor disc in the direction in which the stick is moved. Without the weathercock effect caused by forward flight this control movement results in flight bodily sideways, or in any other required direction, with the fuselage tilting in the same direction as the rotor. Inertia causes a noticeable lag between the initial change of attitude and the subsequent aircraft movement, so *attitude* must be the first concern of the pilot if he is to maintain accurate stationary flight.

7. In the hover, therefore, the stick is used only to control attitude and thus horizontal movement. Height is controlled by the collective pitch lever, and direction by the rudder pedals.

## RESTRICTED

A.P. 129, VOL. 2, PART 2, SECT. 4, CHAP. 12

### Take-Off and Landing

8. Under all normal conditions the helicopter should be hovered for a short period immediately after take-off and before landing. This is done chiefly to ensure true vertical flight on leaving and approaching the ground, and when taking off it also gives an opportunity to check that the C.G. is in the required position before going into forward flight. The hover should be established at a height which gives a safe margin for manoeuvre (with particular reference to the tail rotor position in relation to the ground) and which also ensures the maximum ground effect (less power is required to hover), so obtaining a larger margin of excess power for corrections or emergencies. The recommended height is about the length of one main rotor blade.

9. Any horizontal movement, particularly sideways, must be checked during the time that the weight of the helicopter is borne partly by the rotor and partly by the undercarriage, as movement at this stage causes out-of-balance forces in the rotor system which may lead to ground resonance. While increasing collective pitch and power during take-off, various yawing, pitching, and rolling tendencies are experienced, their strength and combined effects depending on the design of the particular helicopter. These effects must be neutralized by use of the stick and rudder controls so that a clean unstick is obtained without wheel padding, *i.e.* a lateral rocking motion. In the single main rotor/tail rotor type of helicopter the yawing effect is pronounced and increases in magnitude as the aircraft unsticks and friction between the ground and undercarriage is lost. Throughout the take-off r.p.m. must be kept high to avoid the danger of overpitching. A high r.p.m. to power ratio implies a low pitch angle, which prevents the blade drag becoming too great to be balanced by the available power.

10. Landing is a less complicated problem, the chief requirements being a true vertical descent with a light but firm touch-down and a smooth (not sudden) movement of the collective pitch lever to zero as soon as contact is made; the correct use of the collective lever ensures that the period during which the weight is being transferred to the undercarriage is kept to a minimum so that any lateral inaccuracies have the least chance of inducing ground resonance. A sudden downwards movement of the lever could mean that blade lift would be lost equally suddenly with the result that the blades could, in certain circumstances, drop so sharply that they strike against the droop stops. (See para. 82.)

### Take-Off and Landing Out-of-Wind

11. Ideally the take-off and landing should be made into wind but there are times when this is not always possible. The basic take-off and landing techniques apply equally in cross-wind conditions, but in strong winds certain control limitations exist which must be anticipated and allowed for by the pilot.

12. During an out-of-wind take-off the tendency for the rotor disc to flap back in relation to the wind direction must be checked by use of the cyclic pitch stick, otherwise the aircraft moves horizontally when unsticking. In some helicopters the amount of rearward cyclic control available is much less when compared with the amount of forward control, and loss of control can therefore occur during a downwind take-off in a strong wind.

13. Directional control is also impaired during an out-of-wind take-off or hover. Whilst hovering in still air a considerable amount of anti-torque rudder is needed to counteract the torque reaction of the main rotor. If the torque reaction tends to turn the aircraft to port, then right rudder must be used and the amount of right rudder control remaining is thus reduced. If, in addition, there is a cross-wind that tends to weathercock the aircraft to port, then more right rudder is required and in a strong wind full rudder may be insufficient to maintain directional control. During a downwind take-off very accurate directional control must be maintained owing to the weathercock tendency (see also para. 33).

14. All these effects play a part when the helicopter is hovering out-of-wind before landing; if the wind strength is high the pilot should, if possible, test the ability of the machine to hover on the intended heading over an area that is clear of any obstructions before approaching for the actual landing. The selected heading should if possible be one on which the effect of the cross-wind is to turn the aircraft against the torque reaction, *i.e.* assisting the tail rotor, so that the maximum amount of rudder control is available.

15. When heading across wind the helicopter must hover with its rotor tilted into the wind and the fuselage then tends to take up an attitude parallel to the plane of the disc. On descending for the landing one side of the undercarriage therefore touches the ground before the other,

RESTRICTED

making it essential for the touch-down to be made as gentle as possible to minimize the rolling movement as the other wheel comes down. The strength of the rolling moment is considerable owing to the height of the C.G. above the undercarriage (Fig. 1). As the helicopter becomes laterally level during the touch-down, a further rolling effect is encountered owing to the tendency of the rotor disc to tilt away from the wind (flapping due to airflow). This must be countered by continuing to hold the cyclic stick into wind after the landing is complete and until the collective pitch lever is returned to its lowest position.

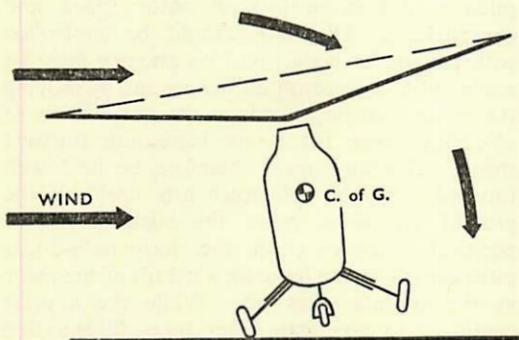


Fig. 1. Cross-Wind Landing

16. Approach and landing downwind should only be made when there is no other alternative. Such a necessity implies an obstructed landing area, requiring a steep angle of approach at a low forward speed; in a strong tailwind this procedure may mean that the helicopter has an effective backward airspeed which is potentially dangerous, not only because of the reduction in directional control but also because rearward cyclic control may be lost owing to disc stability making it impossible to arrest the forward motion of the aircraft. Even when the tailwind is not strong, translational lift is much reduced and the rate of descent must still be kept very low (less than 200 ft. per min.) to avoid encountering the vortex ring state (para. 47).

17. The limiting wind speeds for take-off and landing out-of-wind vary between types of aircraft but 15 knots is an approximate figure. In some tandem rotor configurations the take-off and landing is more easily accomplished in cross-wind conditions, as this eliminates the rotor interference which occurs when the aircraft is headed into wind.

### Landing on Sloping Ground

18. The degree of slope on which a complete landing (*i.e.* the whole of the aircraft's weight transferred to the undercarriage) may be safely made is not very great. Since the angle and direction of the gradient may be difficult to detect in a confined area, all landings on unfamiliar ground must be done with care. The landing technique is basically the same as that used for a normal landing, but great care must be taken to maintain a constant rotor disc attitude and fuselage heading while transferring the weight from the rotor to the undercarriage.

19. As shown by Fig. 2(a), first contact with the ground is made by one main wheel. No attempt must be made to make contact with the other main wheel by use of the cyclic stick, as this would mean tilting the rotor in that direction and the helicopter would begin to fly sideways. Full transfer of the weight to the undercarriage must be made by downward movement of the collective pitch lever, at the same time preventing the rotor from following the change in fuselage attitude by "holding off" with the cyclic stick (Fig. 2(b)). This stage of the landing must be

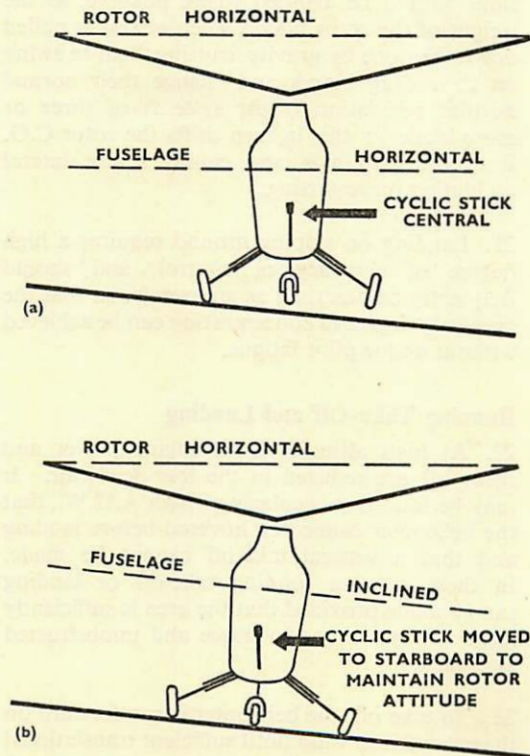


Fig. 2. Landing on Sloping Ground

## RESTRICTED

A.P. 129, VOL. 2, PART 2, SECT. 4, CHAP. 12

carried out carefully; if the cyclic stick reaches its limiting stop before the whole of the undercarriage is on the ground the attempt must be abandoned, as beyond this point the aircraft is uncontrollable and horizontal movement cannot be prevented. If the undercarriage has a castoring nosewheel and the aircraft tends to yaw down the slope, careful directional control must be maintained with the rudder pedals throughout the landing. To assist in this the wheel brakes should be applied during the initial approach.

20. When all wheels are on the ground, the collective pitch must be lowered carefully, as this reduces the lift which may still be required to prevent movement down the slope on a soft or greasy surface. R.p.m. must be kept high during this stage to provide adequate directional control from the tail rotor and to allow for a rapid increase in power for take-off in emergency. In this condition the helicopter is very prone to ground resonance and must be lifted clear of the ground immediately any inaccuracies develop. It may be found impossible to reduce collective pitch completely, but passengers or freight can nevertheless be transferred to or from the aircraft. Stopping the engine and rotor on an awkward slope should be avoided where possible, as the weight of the rotor blades when at rest is pulled down the slope by gravity, causing them to swing on their drag hinges and change their normal angular separation (rotor systems of three or more blades); this in turn shifts the rotor C.G. from the hub axis and causes severe lateral oscillation on restarting.

21. Landing on sloping ground requires a high degree of accuracy of control, and should frequently be practised as an exercise so that the necessary degree of concentration can be achieved without undue pilot fatigue.

### Running Take-Off and Landing

22. At high altitudes both engine power and rotor lift are reduced in the less dense air. It may be found, particularly at high A.U.W., that the helicopter cannot be hovered before landing and that a vertical take-off cannot be made. In these cases a running take-off or landing can be made provided that the area is sufficiently large and has a good surface and unobstructed approach.

23. To take off, the helicopter is run forward on the ground into wind until sufficient translational lift is obtained to lift it clear. The aircraft should first be taxied (para. 26) into line with the

take-off path (that affording the maximum run into wind and lowest obstructions). The cyclic stick should then be held well forward in order to tilt the rotor disc and therefore the total reaction, great care being taken not to cause the blades to strike the droop stops as they pass the forward position. The rotor speed should be raised to the take-off figure by opening the manual throttle, and power then increased further by raising the collective pitch lever. The aircraft then starts to roll forward. As the lever is raised the manual throttle must be opened further to maintain r.p.m. until the throttle is wide open. In this way maximum power is made available for the take-off; any further increase in collective pitch would cause loss of rotor speed and overpitching. Direction should be controlled with the rudder pedals and no attempt must be made to lift the aircraft off the ground by moving the cyclic stick backwards as the only means of obtaining more lift is by increasing forward speed. The stick must therefore be held well forward until the helicopter lifts itself off the ground, at which point the stick is moved positively back to check the sharp nose-down pitch caused by the large forward tilt of the rotor as the aircraft takes off. While the aircraft continues to accelerate after take-off, the stick must be moved steadily forward again to counter flap-back of the disc, the aim being to maintain maximum possible forward tilt of the disc consistent with production of lift, so that translational lift builds up as fast as possible. As the airspeed builds up and translational lift is increased, the r.p.m. tend to rise; this can be countered by increasing collective pitch and so obtaining an effective increase in performance and a steeper climb away.

24. When landing at high altitude, the pilot may have no safe method of checking that the performance is adequate when forward speed and therefore translational lift is lost. The flattest into-wind approach must therefore be chosen and the aircraft brought down in a shallow descent with low rate of descent and an approach speed of about 40 knots. As the ground is approached the descent path should be flattened by gentle backward movement of the cyclic stick so that speed is gradually lost at a height such that the best ground cushion effect is obtained without endangering the tail rotor. Height must then be maintained by increasing the collective pitch and at the same time keeping the rotor speed constant by opening the throttle. As in a running take-off, a point is reached at which full throttle is required to maintain rotor r.p.m.

RESTRICTED

## RESTRICTED

### BASIC HELICOPTER FLYING TECHNIQUES

and beyond which any further increase in collective pitch causes overpitching. When this stage is reached the helicopter must be kept travelling quite straight, with no drift and with a slight nose-up attitude so that forward speed is gradually reduced until the aircraft begins to sink. Care must be taken here to avoid an instinctive upward movement of the collective pitch lever, and to level the attitude with the cyclic stick so that the aircraft touches down with all wheels simultaneously. Collective pitch must then be reduced to zero smoothly and brakes gently applied to bring the aircraft to rest. An accurate touch-down is essential, as any sideways shock or bouncing may easily lead to ground resonance. Excessive flaring must also be avoided as this may cause lift to be lost too quickly to allow the attitude to be adjusted before touch-down; the danger of striking the ground with the tail rotor is also present.

25. It is stressed that a running take-off and landing is used only under conditions where performance is reduced, and must not be used as a means of operating the aircraft at more than the maximum A.U.W.

### TAXYING

#### Introduction

26. The necessity to taxi a helicopter arises very infrequently and is confined, for example, to cases where lack of performance prohibits a vertical take-off and landing. Except in such necessity taxiing should be avoided, particularly over rough ground, as shocks transmitted via the undercarriage to the rotor head may lead to ground resonance.

#### Use of the Controls

27. To taxi, the rotor disc must be inclined forward to provide sufficient thrust to move the aircraft while at the same time producing minimum lift. If too much lift is obtained the aircraft becomes light and unstable on its undercarriage. It is also necessary to obtain the required total rotor reaction by a combination of high r.p.m. and relatively low collective pitch, since a high pitch angle with low r.p.m. increases the possibility of severe blade flapping and hence out-of-balance forces which could lead to ground resonance.

28. The first control action should therefore be to increase r.p.m. to a high figure (approximately that used for take-off and hovering), keeping the collective pitch to zero. The cyclic stick should

then be moved as far forward as permissible for the aircraft type, and the collective pitch then increased steadily until the aircraft starts moving. (On some types the blades can be made to strike their droop stops as they pass the forward position. This must be strictly avoided since it causes severe strain on the blade attachment with the possibility of a subsequent failure.) Once the inertia of the aircraft has been overcome and it is moving forwards slowly the collective lever may be lowered slightly. Forward speed should then be kept low and controlled by use of the collective pitch lever while rotor r.p.m. are maintained with the throttle. No attempt must be made to control forward speed with the cyclic stick, as any rearward movement of this control from its maximum permissible forward position results in an increase in the vertical component of the total reaction and a reduction in the amount of the total weight on the undercarriage. If reduction of collective pitch to zero is insufficient to arrest forward movement, the wheel brakes should be gently applied, and the cyclic stick returned to the central position only when the aircraft has stopped. Directional control is effected by use of the rudder pedals, and when the aircraft is being taxied out of wind the cyclic stick should be positioned slightly into wind to prevent the rotor disc tilting away from the wind, with its associated rolling effect.

#### Special Precautions

29. Great care is necessary when taxiing over rough or soft ground or up a gradient. The power required to move forward may cause the aircraft to begin rising and if this occurs the attempt must be abandoned. The helicopter must also be brought to rest if severe lateral oscillation or fore-and-aft pitching develops. The latter is particularly dangerous and no attempt must be made to correct it with the cyclic stick as this would involve tilting the rotor in the opposite sense to that of the fuselage with a consequent danger of striking the tail cone.

30. It is again stressed that taxiing should be avoided when possible owing to the danger of resonance, and in this connection it should be remembered that a helicopter which is unserviceable for flying is also unfit to taxi.

### SIDEWAYS AND BACKWARDS FLIGHT

#### Introduction

31. For the purpose of manoeuvring in confined spaces the helicopter can be flown sideways or backwards by simply moving the cyclic stick, and

## RESTRICTED

A.P. 129, VOL. 2, PART 2, SECT. 4, CHAP. 12

therefore tilting the rotor, in the required direction. Because the airspeed in sideways and backwards flight is limited to a low figure (para. 35), the amount of translational lift obtained is also low, therefore high power is required and these manoeuvres should normally be done only at ground cushion height.

### Aircraft Characteristics

32. In sideways flight the resultant sideways airflow acting on the tail cone causes a tendency to weathercock along the direction of flight; this must be corrected by use of opposite rudder. The speed of sideways flight is limited by the amount of rudder control required to maintain the heading and so the speed should always be low to ensure the maximum amount of control.

### Control Movements and Disc Stability

33. In backward flight, directional control is also complicated by the tendency of the aircraft to weathercock into wind or into the relative airflow, but when a wind is blowing two further problems arise which demand careful and accurate control and limit the backward airspeed.

34. When hovering into wind, the helicopter has airspeed and therefore translational lift. On beginning to move backwards, translational lift is initially reduced and unless collective pitch and power are increased a sharp loss of height results. As backward airspeed is built up, the stability of the rotor with airspeed causes a tendency for the disc to tilt away from the direction of flight, requiring further backward movement of the cyclic stick to maintain speed; if speed is increased too much the rear stop of the stick is reached, making it impossible to prevent the disc from flapping back (tilting towards the nose) if the speed rises further; the fuselage attitude also changes with the disc. When this forward tilt occurs, or when it is initiated by a forward movement of the cyclic stick to arrest the backward motion, an unstable increase in disc angle of attack occurs, causing the disc to flap further and further forward until airspeed is completely lost. In this condition not only is the helicopter temporarily out of control but full power is required to maintain height owing to the acute inclination of the total reaction. At the higher weights full power may not be enough to maintain height.

### Speed Limitation

35. Sideways and backward flight in confined spaces must necessarily be carried out at very low

speed in the interests of accuracy, and in any condition the speed should never exceed 15 knots. This speed limitation for sideways and backward flight also determines the maximum wind speed for take-off, landing, or hovering out-of-wind.

36. Backward flight naturally implies restricted visibility, and a combination of sideways flight and turning on the spot is usually a safer method of manoeuvring.

### Turning on the Spot

37. This manoeuvre, in which the helicopter is yawed through 360° whilst hovering over a point on the ground, is effected mostly by use of the rudder pedals; in the single main rotor/tail rotor configuration the function of this control is to vary the pitch of the tail rotor blades, thus changing the magnitude of the anti-torque reaction produced. Since the tail rotor is geared to the same drive shaft as the main rotor, an *increase* in tail rotor pitch also increases the drag and causes a reduction in the r.p.m. of the whole rotor system. The loss in rotor r.p.m. causes a loss of lift. A *reduction* in tail rotor pitch causes an increase in lift. These effects must be countered by adjustment of the twist-grip throttle to maintain r.p.m. In still air these are the only considerations, although a certain amount of cyclic stick displacement in the direction of turn is necessary to turn the aircraft accurately in its own length. In a wind, however, the cyclic stick must be displaced into wind throughout the turn to prevent the helicopter from drifting downwind. The length of the tail cone should always be borne in mind, and a good lookout maintained in the *opposite* direction to the turn to ensure that no obstructions endanger the tail rotor.

### Transitions

38. The change from hovering to forward flight or vice versa is called a *transition*, and involves changes in lift and torque which initially present a complex control problem to the student helicopter pilot.

39. To move forward from the hover, the rotor disc must be tilted forward by a forward movement of the cyclic stick. As this is done, there is an immediate loss of lift and height owing to the reduction in ground effect and the forward inclination of total reaction. To keep the height constant a simultaneous increase in collective pitch and power is required. As forward speed increases, however, translational lift is gained and r.p.m. begin to rise. The throttle opening

RESTRICTED

## RESTRICTED

### BASIC HELICOPTER FLYING TECHNIQUES

must therefore be reduced to check the increase in rotor speed and a rudder correction is also required to keep straight because of the change in torque.

40. Transition to forward flight in the downwind direction should be avoided whenever possible, since the initial tendency to lose height is intensified by the loss of translational lift which is obtained during the hover by virtue of *backward* airspeed. Further, the initial forward movement of the cyclic stick results in an unstable increase in disc angle of attack (under the influence of airflow from the rear) and severe nose-down pitching with loss of rearward control may follow.

41. Transition from forward flight to the hover is initiated by a backward movement of the cyclic stick which tilts the rotor disc and total reaction rearward. As speed decreases so does translational lift, and height must be controlled by increasing the collective pitch, care being taken to lead the upward lever movement by opening the throttle, otherwise the consequent fall in r.p.m. causes overpitching. Rudder correction is also required to counteract the increasing torque and keep straight; this also tends to reduce r.p.m. Forward movement ceases with the helicopter in a nose-up attitude. The attitude must then be changed to that for the hover, otherwise a backward movement occurs. As a general rule the process of transition should be done at a height which gives the benefit of the ground cushion but does not endanger the tail rotor in the nose-up attitude.

### OTHER CONSIDERATIONS

#### Circuit Patterns

42. The flying characteristics of the helicopter make the standard fixed-wing circuit procedures unsuitable. It is in fact undesirable for the helicopter to conform to these procedures since they seriously reduce its natural flexibility of operation and potential usefulness. Unless a special procedure is used the helicopter is likely to constitute a hazard and distraction to fixed-wing pilots owing to its low speed and small turning radius; it is therefore essential to have a circuit pattern which allows the maximum flexibility of operation and at the same time provides the minimum interference with fixed-wing aircraft.

43. When helicopters are operating from permanent bases which are also used by fixed-wing aircraft, they should use the opposite

circuit direction to that of the fixed-wing aircraft and a maximum circuit height of 500 feet A.G.L. Since the helicopter circuit is then on the dead side of the fixed-wing circuit, and fixed-wing aircraft do not normally descend below 1,000 feet on this side, a safe separation of the two types is achieved. A portion of the airfield on the helicopter circuit side of the runway in use and bounded by a line parallel to, and at least 75 yards from, the runway should be set aside as a helicopter manoeuvring area. If the runway in use must be crossed, this should be done only after clearance from Air Traffic Control, and then at right angles over the centre of the runway. When leaving or returning to the circuit area the helicopter should fly at 200 feet A.G.L. and cross the centre line of the runway in use at a distance not less than one mile from the perimeter of the airfield.

44. When approaching an unfamiliar airfield the most convenient and accepted procedure is to remain outside the circuit area at a height of not more than 500 feet until called in by the air traffic controller. If the runway in use has to be crossed, this should be done at right angles at the centre of the runway and the helicopter flown to the indicated landing position.

#### Overpitching

45. Overpitching is the term applied to the condition where an excessive blade pitch has led to a high rotor drag which cannot be balanced by engine power. The resulting loss of r.p.m. causes loss of lift and the helicopter sinks uncontrollably, since any further increase in collective pitch only produces a greater loss of r.p.m. Overpitching is most likely to be encountered when at maximum A.U.W. or at high altitude where the maximum engine power is reduced by decreased air density, but it may also be produced by mishandling the controls, an example being the failure to lead with the throttle when increasing collective pitch during a transition to the hover.

46. Although loss of r.p.m. does not necessarily indicate overpitching, the remedial action is similar to that for overpitching and must be immediate. The throttle must be opened fully, and if the r.p.m. are still falling the collective pitch lever *eased* downward with the throttle still held fully open until rotor r.p.m. are restored; the collective pitch can then be readjusted as required.

## RESTRICTED

A.P. 129, VOL. 2, PART 2, SECT. 4, CHAP. 12

### Vortex Ring State

47. The vortex ring state occurs most commonly during a *powered* vertical descent when the rate of descent is much above 200 feet per minute. The symptoms are a pronounced juddering throughout the airframe and a rapidly increasing rate of descent which is only aggravated by an increased collective pitch. If the condition is allowed to continue, the nose yaws and pitches down. As the condition only develops in a vertical descent *relative to the surrounding air*, corrective action must be to move the cyclic pitch stick forward so as to cause forward flight.

48. It must be appreciated that to gain forward airspeed from an uncontrollably high rate of descent may involve a loss of height of about 300 feet. The onset of the vortex ring state when flying close to the ground must be regarded as a parallel to stalling on the approach in a fixed-wing aircraft, *i.e.* to be avoided at all costs. To this end the rate of descent should not be allowed to exceed 200 feet per minute when carrying out a vertical descent or when approaching at a steep angle.

49. The possibility of the vortex ring developing quickly and without warning is probably highest during the final stages of an approach to land when the approach has inadvertently been made with a light tailwind. It is therefore of the utmost importance that the pilot should acquaint himself as fully as possible with the local wind conditions, *however light*, before making an approach to land. In the absence of a positive indication this may be done by flying round the landing area at a low ground speed and noting the drift. Vortex ring state may also be induced when re-engaging the engine after a vertical autorotation unless a definite forward speed is first obtained.

### Ground Resonance

50. The theoretical considerations of this phenomenon are described in Vol. 1, Part 1, Sect. 1, Chap. 16, and from these it is apparent that any out-of-balance force set up in the rotor (by faulty blade damping, sideways motion on landing, or wheel bouncing) may give rise to resonance. To minimize the chances of resonance it is necessary to ensure complete accuracy at all times when taking off or landing. During take-off, an excessive time spent with the helicopter's weight shared between the rotor and undercarriage must be avoided and the aircraft must be lifted positively and cleanly off the ground as soon as it begins to feel "light";

for the same reason the collective pitch must be reduced smoothly and quickly to zero on touch-down. The helicopter is most prone to resonance during a running take-off and landing and particularly while taxiing.

51. The corrective action to be taken if ground resonance occurs varies slightly according to the actual conditions, but basically, as the phenomenon results from contact with the ground, the aircraft should be lifted clear immediately, and if possible the rotor r.p.m. should be changed to alter the relationship between the rotor frequency and the undercarriage oscillation frequency which is causing the resonance. In some conditions, *e.g.* a running landing or taxiing, the power setting may be too low to lift the helicopter clear of the ground quickly enough; when this is so the collective pitch should be reduced to zero, the engine disengaged and the rotor brake applied, the intention being to change the rotor r.p.m. by the quickest means available.

52. It is stressed that ground resonance is a most dangerous condition and if allowed to develop may very quickly result in complete destruction of the aircraft and injury to the pilot. In most contemporary helicopters the possibility of resonance is eliminated as far as possible in the design stage and, given reasonable care and accuracy in flying, need never occur.

### Engine Failure

53. To provide for engine failure a free-wheel unit is fitted in the rotor drive to allow the rotor to turn independently of the engine. If total or partial engine failure occurs, the collective pitch must be immediately reduced to ensure autorotation and the engine switched off. In this condition the aircraft glides at a steep angle and with a high rate of descent, but good control and manoeuvrability are retained. The best airspeed for the glide usually approximates to the recommended climbing speed but, within limits, the angle of descent may be reduced by increasing the airspeed. A further method of flattening the glide is to reduce the rotor r.p.m. by raising the collective lever. Down to a certain limit this results in increased blade efficiency and therefore increased lift, but it is important that high rotor r.p.m. should be recovered before descending below 200 feet. The angle of descent may be increased by reducing the airspeed, to zero if necessary, but ideally a forward speed of about 45 knots is required to build up the r.p.m. by

RESTRICTED

flaring. As the recovery of useful airspeed following a vertical or near vertical autorotation involves a height loss of some 300 feet, it follows that the corrective action for overshooting must be made as early as possible as no effective increase in airspeed can be made below about 300 feet A.G.L.

54. On approaching ground level, forward speed is reduced sufficiently to permit a safe touch-down, usually by flaring (positive rearward inclination of the rotor and fuselage) which itself tends to increase rotor r.p.m. The aircraft is then returned to a level attitude and the higher rotor inertia resulting from the increased r.p.m. enables the collective pitch to be increased sufficiently to check the descent completely just before touch-down. On touch-down, the rotor r.p.m. will be low and, consequently, the coning angle high; the collective pitch should therefore be reduced *smoothly* to zero so as to avoid the blades falling heavily on their droop stops as lift is lost. It should be noted that if the collective pitch is reduced suddenly, the blades will strike their droop stops—therefore a sudden movement must be avoided. When the undercarriage employs skids instead of wheels, the pitch should not be reduced until forward movement on the ground has ceased, otherwise the aircraft may nose-over.

55. On a good surface a touch-down speed of up to 15 knots may be accepted with safety provided the aircraft is kept accurately level and without drift; however, under true forced landing conditions the aim should always be to touch down with zero forward speed. Forward speed should be reduced at as low a height as is safely possible since the rate of descent in vertical autorotation is high, making judgment of the final hold-off difficult. It is also important that the flared attitude should be restored to a level attitude in good time before touch-down, as once the collective pitch is increased the r.p.m. fall, causing (together with a consequent upward coning of the rotor) a progressive loss of cyclic pitch control.

56. **Safety Height Margins.** During the transition from powered flight to autorotation a rapid loss of height may occur, the amount of height lost varying inversely with the airspeed at the time of the engine failure. If the engine fails whilst at a normal cruising speed, the actual height lost during the transition may be greatly reduced by flaring. This increases the rotor r.p.m. and lift and also aids the establishment of

autorotation by inducing the upwards inflow more quickly. If, however, the airspeed is zero, then about 400 feet is lost before full autorotational inflow is established.

57. Unless operationally necessary, therefore, flight with zero airspeed should not be carried out between 400 feet and the maximum height at which ground effect is experienced, *i.e.* about 40 feet. Because engine failure involves a loss of height and the reduction of speed by flaring is only gradual, engine failure at very low heights may have serious consequences if the airspeed is high because it may not be possible to reduce the airspeed sufficiently in the short time available before the aircraft reaches the ground. A typical airspeed/altitude graph for safe autorotative landing is shown in Fig. 3; it should be noted that this graph does not have a general application.

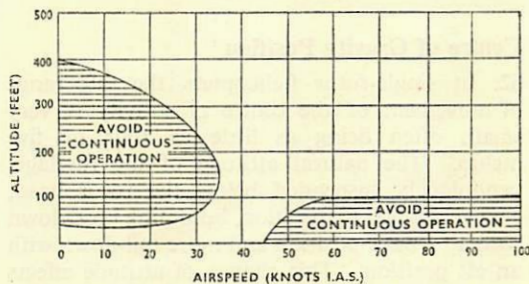


Fig. 3. Typical Airspeed-Altitude Graph for Safe Autorotative Landing

58. It is desirable that the final part of the approach for an autorotative landing should be carried out into wind; it is important to remember that a considerable loss of height will occur during an autorotative turn through 180°. Whenever practicable the minimum height on cross-country flights should be enough to allow for such a turn. Because of the steep angle of descent in autorotation, unnecessary flying over large towns, heavily wooded areas, and large stretches of water should be avoided in a single-engined helicopter.

59. The engine-off landing capabilities of the helicopter provide a degree of safety not found in other aircraft. Engine-off landings should be regularly practised as an exercise by all helicopter pilots, to promote their personal confidence in the aircraft and to ensure that they are able to land successfully after an engine failure.

## RESTRICTED

A.P. 129, VOL. 2, PART 2, SECT. 4, CHAP. 12

### Flying at Maximum All-Up Weight

60. An increase in the A.U.W. requires more power to hover and thus reduces the excess power available for the climb. The performance varies considerably between types of helicopter, but full power may be required in some types to hover at maximum A.U.W. outside the ground cushion, even at sea level and moderate temperatures. Cruising flight (with translational lift) presents no problem, but flight with little or no forward speed should only be attempted at ground cushion height. Large changes in pitch attitude should be avoided, particularly when moving from the hover into forward flight and vice versa, as the loss of lift involved owing to the reduction in ground effect and inclination of the total reaction requires a substantial power increase to maintain height.

61. It should be remembered that the limitation on maximum A.U.W. may be imposed for structural as well as performance reasons.

### Centre of Gravity Position

62. In single-rotor helicopters the safe range of movement of the centre of gravity is very small, often being as little as four or five inches. The natural attitude of the fuselage, pendulously suspended below the rotor head, changes with C.G. position, becoming nose-down with a forward position and more tail-down with an aft position. This change of attitude affects the remaining available angular movement between the rotor disc and the fuselage, and therefore the amount of fore-and-aft cyclic control available. If the C.G. position is beyond the forward limit, therefore, it may be impossible to keep the rotor disc horizontal owing to the extreme nose-down attitude of the fuselage and so impossible to stop the forward movement. Conversely, with a C.G. position beyond the aft limit, forward speed may be severely limited by the cyclic stick reaching its forward stop. As the normal C.G. range is generally forward of the rotor axis some forward speed is usually possible even with the C.G. behind its aft limit, although in severe cases speed may be limited to a few knots.

63. Since operational use of the helicopter involves the carriage of widely differing loads it is essential that the pilot should take care in assessing the weight he is carrying and adjust the C.G. position accordingly. In most single-rotor helicopters the cabin is forward of the rotor axis and therefore increased load leads to a forward movement of the C.G. Adjustment is effected by

moving ballast aft or by stowing a portion of the load in compartments aft of the rotor axis.

64. The safe C.G. range can be considerably increased by using offset flapping hinges in the design of the rotor head. The fore-and-aft range is also greatly increased in the tandem rotor configuration, since the pitching moments may be corrected by differential collective pitch of the rotors rather than by angular tilt.

### Flying at High Altitude

65. The considerations relating to take-off and landing at high altitude have been discussed in para. 22, and it should always be remembered that, even at a comparatively light A.U.W., insufficient performance may be available to enable height to be maintained without forward speed at altitude. At I.C.A.N. standard temperature for the altitude, the most severe fall in performance occurs above the rated altitude for the engine; even so, hovering in the ground cushion is frequently possible above this altitude. The assistance given by the ground cushion in this respect is evident from the fact that the hovering ceiling in the ground cushion exceeds that without this benefit by several thousand feet.

66. For the best rate of climb, I.A.S. must be reduced as height is gained so that a T.A.S. is maintained at which maximum excess horsepower is available in the same way as for fixed-wing aircraft. Maximum indicated cruising speed is also reduced, as the higher blade angle of attack required to obtain lift in the rarefied air causes stalling of the retreating blade.

67. The necessity to fly at high altitudes over the ground does not often arise. However, such a flight requires particular care and accuracy in the control of attitude. Unless the I.A.S. is reduced at these altitudes the cyclic stick position moves progressively further forward with gain in height, leaving less forward control available for attitude correction or manoeuvring. Therefore, if any violent manoeuvre is attempted, forward control may be lost, resulting in a severe nose-up pitch from which the aircraft then "falls away". Visual references become more remote at height causing control of attitude, without reference to instruments, to be more difficult. The pilot is liable to experience vertigo effects.

RESTRICTED

### Flying in Tropical Conditions

68. Conditions of high temperature and humidity cause a loss of performance similar to that experienced at high altitude. This is due to the reduction in engine power and rotor efficiency. The A.U.W. may have to be restricted to a figure lower than the maximum quoted in Pilots' Notes to ensure adequate performance.

### Instrument Flight

69. Instrument flight in the helicopter presents a number of problems which have been the subject of intensive research for many years. One such problem is that of attitude control, since attitude does not vary logically with airspeed as in a fixed-wing aircraft. For instance, it is possible to climb or descend at an airspeed of 45 knots in the same nose-up attitude. Attitude and airspeed must invariably be referred to a power setting, and all three are essential to aircraft control. The artificial horizon becomes a "master" instrument for this reason, as the airspeed indicator does not give an accurate indication of attitude by itself. A modified type of artificial horizon, adjustable in pitch and bank, can be used; however, the problem of instrument failure remains, being temporarily overcome in some cases by the use of two separately driven instruments. Control in hovering flight or in flight at very low forward speed presents further problems; in the first place there must be some reference to the position over the ground, and this is impossible in fully blind conditions with existing instruments without some highly sensitive form of ground position indicator. No such aid is available now. Moreover, existing airspeed indicators are insensitive to very low speeds and changes in pitch attitude at these speeds may occur so rapidly as to defy accurate control.

70. Therefore, when flying in instrument conditions a forward speed of about 30 knots or more is essential. At this speed there is no particular difficulty during cruising flight or when climbing or descending through a layer of cloud when visual flight conditions are known to exist beneath. Use can be made of aids such as G.C.A. or Controlled Descent Through Cloud and, since the recommended speed (about 30 knots) is low, a safe descent may be made to a lower minimum altitude than in a fixed-wing aircraft.

71. For full utilization of the helicopter, the ability to fly under I.F.R. conditions is required of all pilots and should therefore be practised regularly.

### Night Flying

72. Many of the considerations of instrument flight apply to night flight. All helicopter pilots should be able to fly their aircraft by night. Large attitude changes must be avoided at all times (particularly when taking off or when approaching to land). Climbing and descending and the cruising height are all controlled primarily by the use of power. For this reason the pilot should know the approximate power required for each stage of his flight. A landing area of about 50 feet diameter should be marked by lights; most helicopters are fitted with landing lights which should be used as necessary to obtain contact conditions for touch-down. Wind direction must be indicated by some method.

### Starting and Stopping the Rotor

73. A centrifugally operated clutch is incorporated in the rotor drive transmission to allow independent running of the engine for starting. When the engine is running satisfactorily the clutch is brought in to start the rotor turning. This operation must of necessity be done gently to avoid snatching and excessive torque loads on the rotor and transmission drive shafts.

74. It takes some little time to complete the clutch engagement, during which time the rotor blades are prone to blade sailing in high winds. To some extent blade sailing may be minimized by engaging as rapidly as possible consistent with smoothness, whilst holding the cyclic stick in a position which holds the advancing blade down as cyclic control becomes effective. During the run-down the rotor should be braked as quickly as possible whilst holding the stick in a similar position.

75. These precautions are, however, only effective in windspeeds of up to about 25 knots and beyond this speed blade sailing may be unavoidable. It should be noted that the helicopter should be started up and run down well away from obstructions and *not* between or in the lee of hangars where the effects of a gusty wind are intensified. In cases of urgent operational necessity the helicopter may be started up inside a cleared hangar and then taxied outside for take-off, or landed outside and taxied in for run-down. This emergency procedure must be carried out under the direct supervision of a squadron or flight commander.

76. The limiting windspeed for start-up or run-down is increased in some designs by having

## RESTRICTED

A.P. 129, VOL. 2, PART 2, SECT. 4, CHAP. 12

centrifugal droop stops which hold the blades at a higher angle relative to the fuselage below certain rotor r.p.m.

77. Blade sailing is especially likely when starting up or running down in the gusty conditions caused by another helicopter operating in the close vicinity, or in the slipstream of fixed-wing aircraft. For this reason all other aircraft should not manoeuvre in the vicinity of a helicopter while it is starting up or running down. It is the responsibility of the helicopter pilot who is about to start or run-down to check that no other machine is manoeuvring within this distance. This does not preclude helicopters from being operated from confined dispersal areas, as the danger only exists when rotor r.p.m. are very low. When rotor engagement is complete, ample cyclic control is available and the rotors of other machines at rest may be held by hand if necessary to prevent excessive flexing while a nearby helicopter is landing or taking off.

### Icing

78. A slight degree of carburettor icing, which may not be noticed in cruising flight, may cause a significant loss of power when the throttle is opened to establish a hover.

79. Airframe icing is very much more serious in a helicopter than in a fixed-wing aircraft for the following reasons :—

(a) Since the wing loading (*i.e.* blade loading) of the helicopter is generally very much higher than that of most fixed-wing aircraft (*e.g.* the wing loading of the Dragonfly is about three times that of the Provost), a small amount of ice accretion on the blades is likely to have a very large effect on rotor performance.

(b) Increase in blade weight due to ice accretion causes a significant increase in the centrifugal reaction and therefore may impose unacceptable loads on the rotor hub.

(c) Slight inequalities in the amount of ice accretion on individual blades cause blade unbalance and, since blade balance is very critical, severe vibration may result.

(d) In some cases, ice accretion on the rotor head itself may interfere with the system for controlling the blades.

80. It may even be dangerous to carry out ground running of the rotor in foggy conditions with very low ambient temperatures when ice

may form on the blades. Apart from the risk of ground resonance resulting from blade unbalance, lumps of ice may be thrown off at a high speed.

81. Helicopters should not be flown in icing conditions. If icing is encountered during flight a landing should be made as soon as possible and the ice allowed to disperse before taking off again. The use of de-icing paste has been proved to be ineffective; only when a comprehensive de-icing system is available for the blades and rotor head will prolonged flight in icing conditions be safe.

### Overcontrolling with the Cyclic Pitch

82. Fundamentally, excessively large and rapid changes of the disc attitude cannot be made without the risk of the blades striking their droop stops. When the disc attitude is changed too rapidly, the inertia of the fuselage causes its movement to lag behind the disc movement and therefore the clearance between the blades and their droop stops decreases until impact occurs. When the blades strike their droop stops a severe strain is imposed on the blade attachment and structural failure can follow.

83. The blades can be caused to strike their droop stops as they pass across the tail cone by :—

(a) Moving the control column violently through an excessively large rearward movement while the aircraft is at a high forward speed, particularly if the C.G. is fully forward and the aircraft is diving.

(b) Making a too violent transition from a vertical descent or ascent to horizontal flight, and then over-correcting by a sudden rearward movement of the control column.

84. The clearance between the blades and their droop stops decreases as the coning angle decreases. Therefore the higher the rotor r.p.m. (the lower the coning angle) the less can the disc be tilted during manoeuvres before the droop stops are struck. This applies particularly in autorotation, when the rotor r.p.m. are higher than in powered flight, and therefore large and rapid movements of the cyclic stick must be avoided. The entry into an autorotation is especially important, since the sharp reduction of collective pitch produces, momentarily, a very low coning angle.

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