PART 2 : SECTION 3

CHAPTER 2

TAKE-OFF, CIRCUIT, APPROACH, AND LANDING

Check Lists

1. Because of the complexity of most aircraft it is essential to check and preset the flying and engine controls before taking off. Systematic checks of vital actions have been introduced to cover these items. These checks should be kept as brief as possible without compromising their thoroughness, and any control setting that does not concern the take-off should be checked either before starting in the case of jet-engined aircraft or during the warming up period in piston-engined types. In aircraft with complex cockpits the items concerned are listed in check lists carried in the aircraft. On aircraft having powered flying controls the detailed checks and precautions regarding the controls given in Pilot's Notes must always be meticulously observed. On all aircraft the flying controls should be tested over their full range of movement for freedom and for operation in the correct sense. Any unusual sound, slackness, tension, or restriction should be investigated.

2. To help remember the check lists certain mnemonics have been designed to cover the requirements of piston-and jet-engined aircraft. The pre-take-off mnemonics are T.M.P.F.F.G.H.H. for piston-engined aircraft and T.A.F.F.I.O.H.H. for turbo-jet-engined aircraft. These letters signify particular cockpit items (detailed below) which must be checked before take-off. To conserve fuel in jet aircraft, as many as possible of the pre-take-off checks are normally done in dispersal before starting the engines or taxying. After taxying clearance has been obtained, the pre-take-off mnemonic is repeated, as a further safeguard, *en route* to the marshalling point. The checks for piston-engined aircraft are done at the marshalling point.

Jet-Engined Aircraft

T. Trims
A. Airbrakes
F. Fuel
F. Flaps
I. Instruments
O. Oxygen
H. Hoods and hatches
H. Harness

Piston-Engined Aircraft

T. Trims, temperatures
Throttle friction
M. Mixture, including carburettor controls
P. Propeller pitch. Pressures
F. Fuel. Cocks and contents
F. Flaps
G. Gills or radiator shutters. Gyros
H. Hoods and hatches.
H. Harness

These basic mnemonics seldom need to be modified, though it may be necessary to make additions or omissions to suit a particular type of aircraft.

3. After obtaining take-off clearance, ensure that the approach and take-off area is clear, then line up for take-off on the port or starboard side of the runway. (Use of the sides rather than the centre doubles the runway life.)

TAKING OFF

Factors Affecting Length of Run

4. The length of the take-off depends on :—

(*a*) All-up weight (A.U.W.).
(*b*) Amount of flap used.
(*c*) Engine power.
(*d*) Wind velocity.
(*e*) Nature of the runway surface.
(*f*) Air temperature.
(*g*) Airfield elevation.

5. **All-Up Weight.** Since the stalling speed is proportional to the weight, if the weight is high the aircraft has to be accelerated to higher I.A.S. than that required at a lower weight before the wings generate sufficient lift. Further, because the weight is higher, the inertia is greater and therefore the rate of acceleration is reduced ; both effects lengthen the take-off run.

6. **Amount of Flap Used.** Thin wings, swept or unswept, have low maximum lift coefficients and therefore need to be accelerated to higher

speeds than comparable wings with thicker aerofoils, so again a longer run is required for unsticking. Use of take-off flap increases the lift and enables the aircraft to become airborne at a lower I.A.S., and therefore a shorter run ; the flap setting for take-off is given in Pilot's Notes. On aircraft with high unstick speeds and wing loadings the take-off flap setting should always be used when taking off at a high A.U.W.

7. **Engine Power.** The greater the thrust available in a given airframe the better will be the acceleration and the less the distance required to become airborne.

8. **Wind Velocity.** If the aircraft is taken off into wind the take-off run is shortened because an aircraft at rest, pointing into wind, already has an I.A.S. equivalent to the wind speed. The additional advantages of taking off into wind are :—

(*a*) The ground speed at the time of unsticking is lower.

(*b*) At the lower ground speed the stresses on the undercarriage and tyres are reduced.

(*c*) There is no tendency to drift.

(*d*) Directional control is improved in the initial stages of take-off.

(*e*) The *angle* of climb after take-off is steeper because, while the rate of climb is unaffected, the ground speed is lower (Fig. 1).

(*f*) The ground speed is lower following possible engine failure or an abandoned take-off, so that the touch-down is made more slowly and the distance to run is shorter.

9. **Nature of the Runway Surface.** The retarding effect of a rough surface such as grass, rutted and frozen snow, or soggy ground, increases the ground run required. If the ground has regular corrugations, a pitching oscillation (porpoising) may be set up which gains in intensity and results in the aircraft being thrown into the air before flying speed is reached.

10. **Air Temperature.** The low air density at high temperature raises the T.A.S. required to unstick and so lengthens the take-off run. Low air density also reduces the maximum power of all engines, an effect which adds to the distance covered. ▶The thrust of jet engines is reduced by four to five per cent. for each 10°F. rise in ambient temperature above standard (60°F.).◀

11. **Airfield Elevation.** Again, the reduced density at altitude increases the take-off run for reasons explained in the paragraph above. ▶The thrust of jet engines is reduced by two to three per cent. for each 1,000 ft. increase in airfield elevation.

Allowances to be Made to Jet Aircraft Take-Off Distances when Conditions Deviate from Standard

11A (*a*) For each 10°F. rise in temperature above standard (60°F.), or each 1,000 ft. increase

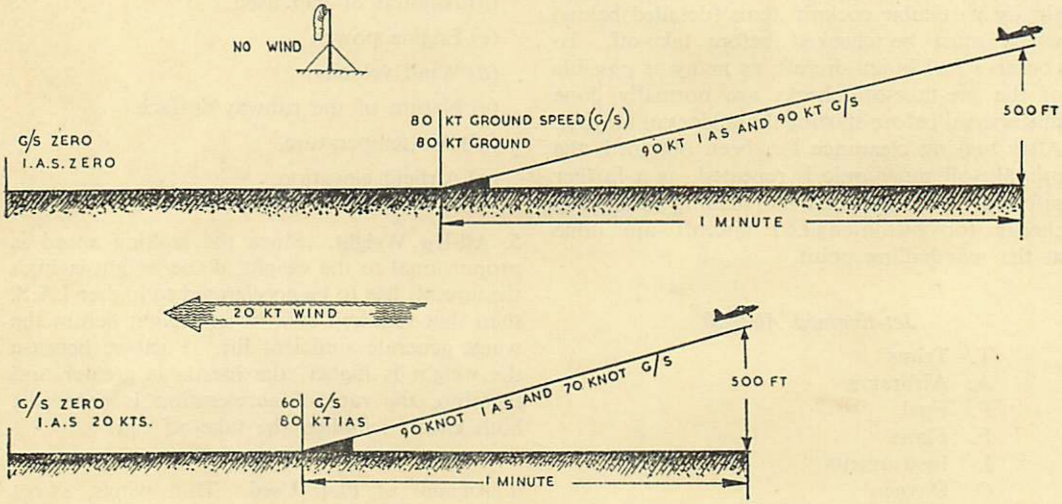


Fig. 1. Effect of Wind on Take-off Run and Initial Angle of Climb

(*A.L.* 4, *Mar.* 58)

in aerodrome elevation above sea level, the calculated take-off distance should be increased by 10 per cent.

(*b*) For clearing obstacles, convert the obstacle height in feet into per cent. and increase the take-off distance accordingly, *e.g.* for a 25-ft. obstacle the required take-off distance should be increased by 25 per cent.

Acceleration Check Speed

12. Acceleration check speed is the speed an aircraft should attain at a predetermined point during take-off. The purpose of checking speed against distance gone, is to ascertain the aircraft's performance. The actual acceleration of an aircraft during take-off depends on the thrust/weight ratio although drag must also be considered; thus it is possible to calculate the speed an aircraft should reach at a certain point. If the aircraft's speed at the acceleration check point is at least equal to the predetermined speed, performance is satisfactory and the take-off should be continued; if the speed is less, the take-off should be abandoned since the lack of speed is an indication that correct thrust is not available or that some other defect like binding brakes is present. Further, if the take-off is continued the lower rate of acceleration will lengthen the take-off run possibly to a dangerous extent.

13. So that the aircraft can be stopped on the runway remaining if the check speed is not attained, the Vstop (stop-speed) must also be considered. The Vstop is defined as the maximum speed from which an aircraft can be brought to rest on the runway remaining, and the Vstop data is obtained from a series of actual acceleration/stop tests during which an aircraft is accelerated to a particular speed simulating take-off, and the throttle is then closed simulating engine failure. After a delay equivalent to pilot reaction time (usually three seconds) the brakes are applied. The distance, associated with each speed, from the throttle closed point to the stop point is measured and

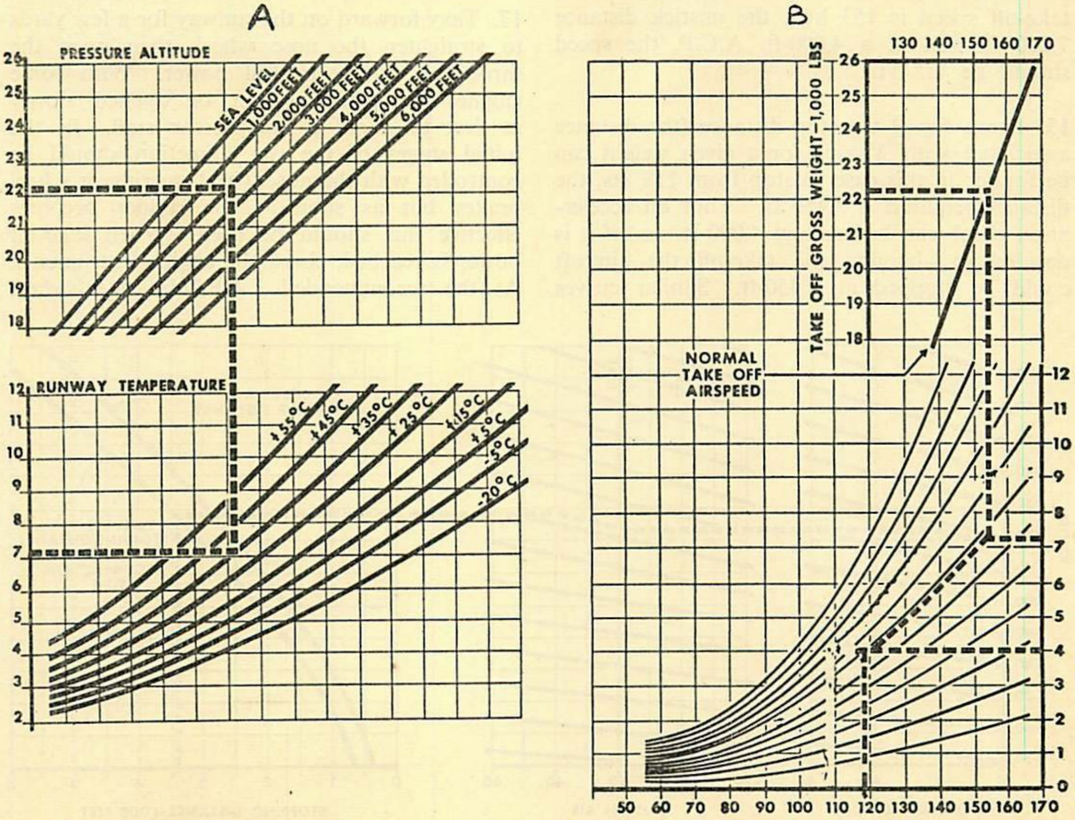


Fig. 2. Method of Calculating Acceleration Check Speed

(*A.L.* 4, *Mar.* 58)

plotted. The stop speed will vary with weight, runway length and slope, wind, temperature, and altitude.

14. The acceleration check is thus made at a point which is both late enough to be a useful acceleration check and early enough for the aircraft to be stopped on the runway remaining if the correct speed is not attained. Figs. 2 and 3 show how a check speed can be calculated. Consider a hypothetical example; given the following conditions determine the speed at a 4,000-ft. acceleration check point:—

Take-off weight	22,300 lb.
Pressure altitude	2,000 ft.
Temperature	+35°C.
Runway length	9,000 ft.

Normal dry runway surface
Zero wind conditions.

Enter the graph Fig. 2A at 22,300 lb. and follow the broken line to read off an unstick distance of 7,250 ft. Then enter the graph Fig. 2B again at 22,300 lb. and follow the broken line to read off an I.A.S. of 118 kts. We now know that the take-off speed is 153 kts., the unstick distance 7,250 ft. and at a 4,000-ft. A.C.P. the speed should be 118 kts.

15. From Fig. 3 the stop distance (the distance associated with Vstop) for a given weight can be found; in this case to stop from 118 kts. the distance required is 3,450 ft. Thus an acceleration check can be made at 4,000 ft. and if it is decided to abandon the take-off the aircraft could be stopped at 7,450-ft. Similar curves can be provided for any type of aircraft and allowances can also be made for runway gradient, prevailing wind, and for varying weight on the stop distance graph. ◀

Take-Off Technique

16. The take-off technique varies with different classes of aircraft. The main classes of aircraft from this point of view are:—

(*a*) Single turbo-jet engine and nose-wheel undercarriage.

(*b*) Single piston engine and tail-wheel undercarriage.

(*c*) Multi-turbo-jet engines and nose-wheel undercarriage.

(*d*) Multi-piston engines and tail-wheel undercarriage.

(*e*) Multi-piston engines and nose-wheel undercarriage.

Single Turbo-Jet Engine and Nose-Wheel Undercarriage

17. Taxy forward on the runway for a few yards to straighten the nose wheel, then open the throttle smoothly to full power. With some engines the throttle must be opened slowly at first to avoid a compressor stall. In the initial stages of the run, direction should be controlled with the nose-wheel steering or wheel brakes but as soon as the rudder becomes effective this should be used. When take-off power is reached, check the engine instruments. At the recommended I.A.S. the nose wheel

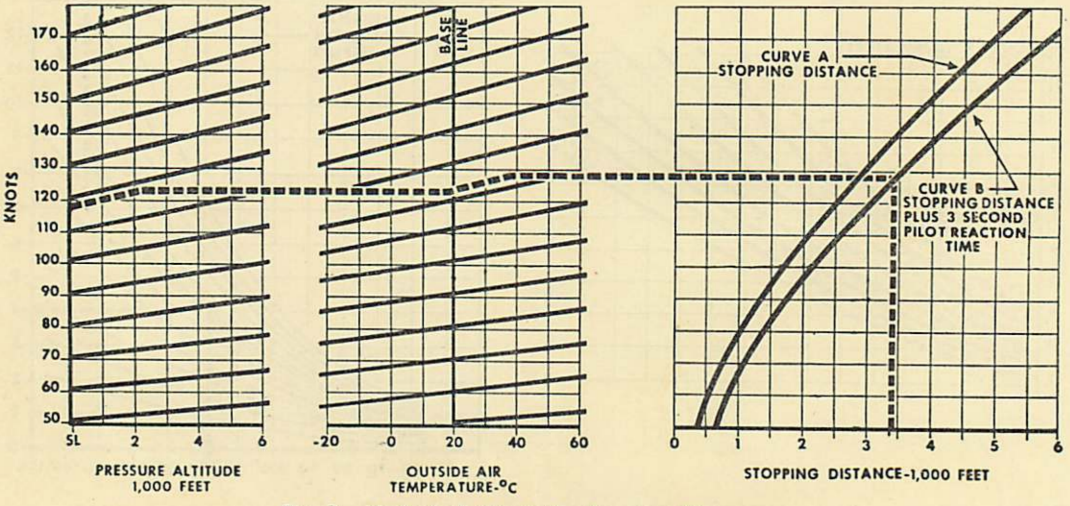


Fig. 3. Method of Calculating Stopping Distances

should be raised clear of the runway, thus setting a *moderate* nose-up attitude which should be maintained until the unstick speed is reached. As the speed rises above the nose-wheel lift-off speed, the elevator effectiveness increases and there is a tendency for the attitude to become more nose-up. This must be countered by a suitable control movement because, if the nose-up attitude becomes exaggerated the drag rises to an extent which reduces the rate of acceleration and, in extreme cases, may prevent any further acceleration. When the recommended unstick speed is reached, the aircraft should be lifted off the ground with a smooth, definite backward pressure on the control column. When safely airborne a slight touch of brake should be applied momentarily to stop the wheels spinning, and the undercarriage retracted whilst a shallow climb is maintained and the I.A.S. allowed to increase to the initial climbing speed. Flaps, if used, should also be raised, and the control column moved to counter any tendency to sink. If climbing power is less than full throttle, power should be reduced when the climbing speed is reached. A slightly shorter take-off run is obtained by first opening up to the maximum power that can be held on the brakes, then releasing the brakes and applying the rest of the power.

18. **Use of Reheat.** When reheat is used for the take-off, no special technique is necessary other than a check of the reheat operation (see Vol. 1, Part 1, Sect. 3, Chap. 9) and the undercarriage and flaps raised as soon as possible after becoming airborne; this is necessary (because of the rapid acceleration) to prevent exceeding the limiting I.A.S. for these items.

Single Piston Engine and Tail-Wheel Undercarriage

19. Taxy forward for a few yards to straighten the tail wheel and then, if applicable, lock it. With the stick held aft of central, open the throttle smoothly to take-off power. Any tendency to swing should be corrected with the rudder, the corrections becoming smaller as the rudder becomes more effective with increasing airspeed. As the speed increases, the aircraft should be brought into the flying attitude by a progressive forward movement of the control column, taking care not to get the nose too low. When flying speed is reached, a smooth back pressure on the control column lifts the aircraft into the air. When safely airborne, brake slightly to stop the wheels turning and retract the undercarriage while maintaining a shallow climb and allowing the I.A.S. to build up to the climbing speed. At a height which allows for the possibility of sinking, the flaps, if used, should be raised. When the flaps and undercarriage are fully retracted, power should be reduced to the climbing setting.

20. **Directional Instability.** The inherent instability on the ground of the tail-wheel-type undercarriage requires more care to be taken with the directional control of the aircraft. Any slight swing which is not quickly corrected gains in strength. A piston-engined aircraft with a tail wheel has certain inherent characteristics which tend to cause it to swing on take-off. These are discussed below.

21. **Slipstream Effect.** The slipstream from the propeller rotates around the fuselage and tail surfaces in a spiral path so that the airflow meets the fin at an angle of attack, setting up a force which causes a tendency to swing.

22. **Gyroscopic Effect.** As the tail rises into the flying attitude the inclination of the plane of rotation of the propeller changes. This change of inclination sets up a precessing force on the propeller, which, having gyroscopic properties, causes a further swing tendency.

23. **Asymmetric Blade Effect.** While moving with the tail on the ground, the propeller disc is tilted backwards. In this attitude the relative airflow on the down-going blades differs from that on the up-going blades. On the down-going

(*Continued on next leaf*)

blades the angle of attack is greater and the relative speed higher. Thus the down-going side of the disc produces more thrust than the up-going side, and so applies another yawing force on the aircraft.

24. **Torque Effect.** The equal and opposite reaction to the force which rotates the propeller results in a tendency for the airframe to be rotated in the opposite direction. On take-off this torque force causes one wheel to be pressed more firmly on to the ground, causing more friction (tantamount to braking) on that side and yet one more yawing force. The throttle should be opened at such a rate that the amount of torque set up is controllable by the rudder ; on high-powered piston engines, opening the throttle rapidly at the start of the take-off results in an uncontrollable swing owing to the high torque and the ineffectiveness of maximum corrective rudder movement at the low speed.

25. All these yawing forces act in the same direction, and are countered, during take-off, by use of the rudder. Viewed from behind, when the propeller rotates clockwise, all these forces tend to yaw the aircraft to the left, and vice versa.

Multi-Turbo-Jet Engines and Nose-Wheel Undercarriage

26. The take-off technique for these aircraft is the same as that for single-engine types, except that the possibility of engine failure during and immediately after take-off must be considered. These considerations are detailed in Part 4.

27. When Operating Data Handbooks are available for use with any aircraft type, the particular acceleration check speed and maximum refusal speed for the take-off conditions and runway length should be ascertained. When the aircraft reaches the acceleration check point, the I.A.S. should be at or above the desired figure. The maximum refusal speed governs the actions following engine failure during take-off.

Multi-Piston Engines and Tail-Wheel Undercarriage

28. The yawing effects described in paras. 21 to 24 apply to a varying degree to this type of aircraft, unless the propellers are *handed*, *i.e.* rotate in opposite directions on opposite sides of the fuselage. However, if directional control is not easy during the early stages of the take-off run, the throttles should be opened differentially, and rudder used at the same time. The technique following engine failure is discussed in Part 4.

Multi-Piston Engines and Nose-Wheel Undercarriage

29. Since a multi-piston-engined aircraft with a nose wheel is almost in the flying attitude, the asymmetric blade or gyroscopic effects during the take-off run will not be felt until the nose-wheel is lifted off the ground, and even then the effect will be negligible. Some nose-wheels are steerable and can be used to maintain directional control during the early part of the take-off run. If an engine fails before becoming airborne the steerable nose wheel should be used to help to keep the aircraft straight. Otherwise the technique is the same as for other aircraft using nose-wheel undercarriages.

Taking Off in a Cross Wind

30. Because of the advantages listed in para. 8, it is usual to take off as nearly as possible into wind. However, when a long take-off run is needed it may be preferable to use the longest run regardless of the wind direction, unless the wind is very strong. All else being equal, a cross wind take-off requires a longer run since the head-wind component is lower.

31. **Drift.** For a given wind speed the drift is inversely proportional to I.A.S. ; the lower the I.A.S. the greater the drift. Consequently the amount of drift correction when unsticking is less at higher speeds. Nose-wheel aircraft, being inherently stable on the ground, have a reduced tendency to weathercock when taking off across wind.

Technique for Cross-Wind Take-Off

32. An aircraft tends to weathercock into wind and this tendency must be anticipated. In the initial stages the controls should be handled as for a normal take-off, paying extra attention to directional control. In multi-engined aircraft, directional control may be assisted by differential use of power ; but it must be appreciated that this lengthens the take-off run as more time is needed before full power is reached. When the unstick speed is reached the aircraft should be lifted cleanly off the ground and must be prevented from dropping back on the runway. A clean unstick is especially important when taking off from a rough surface, or in gusty conditions, when an unexpected bump may force the aircraft into the air before full flying speed has been reached. In these circumstances it is advisable to hold the aircraft down deliberately until a speed slightly above the normal take-off speed is reached. In all aircraft,

more particularly those with sweep-back, a cross wind may cause the into-wind wing to rise immediately after unsticking. This tendency should be expected, and corrected as soon as it starts ; it is a transitory effect which disappears as soon as the wind has overcome the inertia of the aircraft and causes it to drift. After unsticking and until the drift develops, there is a "yawed" airflow over the wings which causes the effective aspect ratio of the into-wind wing to be momentarily increased. As soon as the aircraft is airborne the nose should be yawed into wind to counteract the drift so that the aircraft continues to track along the line of the runway after take-off. The yawing of the nose may be accompanied by a rolling tendency towards the into-wind wing ; this should be anticipated and is easily corrected by a suitable aileron movement co-ordinated with the rudder movement ; the rate of roll with yaw is proportional to the rate of rudder movement; the effect is most noticeable again in swept-wing aircraft.

THE CIRCUIT

Introduction

33. To reduce congestion and the risk of collision, aircraft should enter the airfield circuit in a planned and systematic manner. To achieve this a standard circuit procedure is taught.

Preliminaries to Joining the Circuit

34. As the airfield is approached, the following preparations for the final approach and landing should be made while maintaining a continuous look-out for other aircraft using, leaving, or joining the circuit :—

(*a*) Contact should be established between the aircraft and air traffic control (A.T.C.), and permission obtained to enter the circuit.

(*b*) If necessary, reset the altimeter.

(*c*) Adjust and lock the safety harness.

(*d*) Check brake pressure (if applicable).

(*e*) Set the engine power to give the required circuit speed.

(*f*) Check the fuel state and if necessary select the best tank.

(*g*) Lose height to the authorized minimum above the airfield.

Procedure for Joining the Circuit

35. Enter the circuit (Fig. 4) at a slow cruising speed and at a height not below 2,000 feet above the ground ; fly over the aerodrome to check the ground signals and wind conditions. When the dead side of the airfield (the side not normally used when carrying out a circuit and landing) is reached, turn in the direction of the circuit to fly on a parallel to the landing path. Reduce the height to circuit height and turn across wind

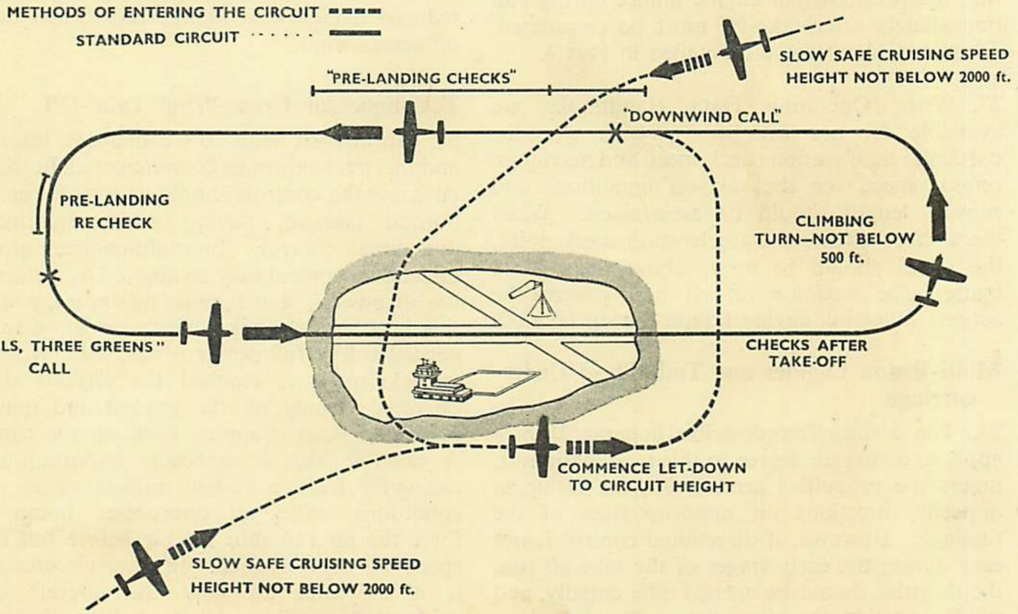


Fig. 4. The Circuit Pattern

sufficiently close to the up-wind boundary to enable aircraft taking off or overshooting to pass safely underneath. When flying at circuit speed, partial flap may be used to improve the handling characteristics.

36. If the circuit conditions are known beforehand, *i.e.* the direction of landing and the nature and amount of traffic, the circuit may be joined at circuit height direct onto the down-wind leg, or onto the cross-wind leg up-wind of the airfield.

Circuit Pattern

37. The aircraft should be flown across wind until it is at a suitable distance from the airfield, then turned down wind and parallel to the intended landing path and the "Downwind" call made to air traffic control when opposite the ▶up-wind◀ end of the runway. The pre-landing checks should be done on the down-wind leg. When a suitable position down wind has been reached (this will depend on the wind strength and the type of approach being made) turn onto the base leg of the circuit. On this leg, before the final approach is begun, re-check the pre-landing vital actions *and verify that the undercarriage is down.* When the turn onto the final approach is started make the "Finals" call to air traffic control, ending with the words "Three greens"to indicate that the undercarriage has been checked. The pre-landing check list is given in Pilot's Notes.

THE APPROACH

Introduction

38. The first requirement of a good landing is a good approach. The approach may be made with or without assistance from the engine. An engine-assisted approach is usual, but the pilot must be capable of making a glide approach in any type of aircraft so that he is competent to perform a forced landing if the engine fails.

Use of Flap on the Approach

39. The use of flaps during an approach will give the pilot:—

(*a*) A steeper path of descent at a given speed.

(*b*) A lower stalling speed, thus permitting an approach at lower airspeed without reducing the safety margin.

The amount of flap used will depend on the type of aircraft and the wind conditions prevailing. In heavier aircraft it is advisable to use full flap on almost all occasions; but in lighter aircraft in a strong wind, or in cross-wind conditions, it may by preferable to use only partial flap. It is impossible to formulate general rules about the use of flap, but a pilot should learn from his experience the degree of flap most suited to the various wind conditions in his type of aircraft. In general, it is normal to use partial flap during the early stages of an approach and to select full flap when the aircraft is entering its final approach. When approaching with asymmetric power it is particularly important to defer the use of full flap until finally committed to the landing.

Effect of Wind

40. The two main advantages of making an approach and landing into wind are that the ground speed is reduced to a minimum for a given airspeed, and drift is eliminated. Consequently the landing run will be shortened, the undercarriage will not be subjected to unnecessary side loads, and the tendency to swing will be reduced. Also, if it is necessary to go round again, the aircraft will be in the best position to regain height rapidly.

Wind Gradient

41. A progressive decrease of wind speed in the lower layers near the ground, *i.e.* wind gradient, will be most pronounced when a strong wind is blowing over an uneven surface. The effect of a sharp wind gradient on an aircraft approaching to land is to cause a sudden reduction in I.A.S. With operational and advanced aircraft, which usually approach at a speed close to stalling speed, this reduction may cause a rapid sink and a heavy landing, or at worst an undershoot. The gradient is sometimes aggravated by a downdraught which greatly increases the rate of sink. Therefore if a strong wind gradient is suspected the approach should be made at a higher speed than normal and extra power used to prevent the aircraft sinking rapidly as it nears the ground.

Gustiness

42. Gusts are caused by eddies and thermal currents and may blow from any direction. They are strongest when the wind is strong and on hot days, when the effect of thermal currents caused by the uneven heating of the earth's surface is also most pronounced. In conditions of moderate to high wind they may also be caused by the horizontal shielding effect of buildings and trees. The effect of gusts is similar to that of a wind gradient except that a sudden increase in airspeed and lift may also occur.

Manoeuvrability

43. At the low speeds used on the approach, the amount of bank and hence *g* that can be applied is limited. The higher the landing weight, the higher the stalling speed and the less the amount of bank that can be safely used at a given speed. Whereas,for example, 45° of bank could be safely used when turning onto the final approach, the same amount of bank used at a lower speed at some stage of the final approach could induce the beginnings of a stall and considerably increase the rate of descent. This consideration applies particularly to aircraft having combinations of high wing-loading and sweep-back and when operating at or near the maximum landing weight.

Engine Handling

44. With turbo-jet and turbo-prop engines, Pilot's Notes stipulate the minimum r.p.m. that should be used on the approach until definitely committed to the landing. This figure is important, because if the aircraft undershoots with the r.p.m. below this figure the poor engine acceleration characteristics may entail a considerable and possibly disastrous delay before sufficient power is reached to correct the approach path. In addition, with the r.p.m. below the required figure, any attempt to hasten the build-up of power can cause a compressor stall. Unless necessary, therefore, landings requiring steep approaches needing little or no power should be avoided.

Approach Path

45. The classic form of approach is that during which height, speed, and power are progressively reduced until the aircraft arrives at the touchdown point with the engine throttled back and the speed at its lowest value above the stall. This form of approach is used on most types of aircraft. An alternative method that is suitable for large aircraft having a high wing-loading and landing at high weights is to set a constant speed immediately after starting the final approach; thereafter the approach path and rate of descent is controlled through throttle movement; the speed used, the runway threshold speed, is governed by the landing weight, wind conditions, and air temperature, and is that speed at which, using the classic technique, the round-out is commenced.

46. Irrespective of the type of approach, the aim should always be to maintain a constant and comfortable rate of descent. Steep approaches with a high rate of descent and little or no power, or flat approaches with a low rate of descent and a high power setting, are indicative of poor judgment and airmenship. Although some circumstances may demand such approaches they should not be used under normal conditions since, being extremes, the margins of safety are reduced.

47. On aircraft having high wing-loadings, particularly those with sweep-back, the rate of descent must be kept moderate. If the speed is low and the rate of descent high, a comparatively large amount of height and power is needed to check the descent and, at the low speed, any attempt to hasten the correction can easily cause a *g* stall. The implications of these characteristics are all important during the approach.

48. A steep approach at the correct speed implies the use of low power; this conflicts with the requirements for gas-turbine engines stated in para. 44. A high rate of descent can only be checked quickly with the assistance of the engine and, by virtue of the low power setting used, this assistance may be denied when it is most needed.

LANDING

Definitions

49. The final approach is considered to start from a point where the aircraft is some distance down-wind of the runway, in line with it, and approaching on a descending flight path. The *round-out* is the change of attitude made from the descending path of the approach to a path level with, and slightly above, the ground (commencing at the runway threshold speed stated in Pilot's Notes). The *hold-off* or *float* describes the subsequent period in which the aircraft is flown parallel to the ground with increasing angle of attack and falling airspeed until the aircraft touches down.

Nose-Wheel Aircraft

50. **Basic Technique.** As the aircraft approaches the threshold of the runway the rate of descent should be checked by a gentle backward pressure on the control column. At the same time, the throttle should be closed gradually. In this attitude the airspeed decreases and the aircraft should be lowered gently onto its main wheels. If after rounding out there is a tendency to float or gain height, the nose has been raised too high

(*A.L.* 4, *Mar.* 58)

during the round-out; the nose should be lowered slightly, and the main wheels deliberately run onto the ground, so avoiding any tendency to float. The rate at which power is reduced is not the same for all aircraft; some types, particularly highly loaded aircraft and those using swept wings, require some power during the round-out to prevent an excessively rapid drop in speed due to the high drag in the nose-up attitude. Unless power is used to prevent this, the rate of descent can increase causing an undershoot (see para. 47).

51. An aircraft with a nose-wheel undercarriage should be landed on the main wheels with the nose wheel held off the ground. This attitude is little different from the attitude of the aircraft while on a normal approach, and therefore only a small change of attitude is required when rounding out. Since the C.G. is ahead of the main wheels, the aircraft tends to pitch forward onto its nose wheel on touch-down. This reduces the angle of attack so that there is no tendency to balloon off the ground. The nose wheel should be lowered onto the ground before the brakes are used, but on some aircraft the nose wheel cannot be held off the ground once the main wheels have touched down. Brakes should then be used to decelerate and, if necessary, maintain a straight landing run. Even if a long runway is in use, the brakes should be applied briefly as soon as the nose wheel is on the ground as a check of serviceability; thereafter the brakes should be used as required.

Aerodynamic Braking

52. Aerodynamic braking consists of holding a nose-wheel aircraft in a marked tail-down attitude for the first part of the landing run, so offering the largest possible area to the airflow, giving more drag and slowing the aircraft while reducing the amount of brake required subsequently. If aerodynamic braking is used the landing run is longer than if the nose wheel had been placed on the runway and the wheel brakes applied at the earliest possible moment. Prolonged aerodynamic braking is useful only when there is sufficient runway available or if the brakes have failed.

Tail-Wheel Aircraft

53. **Basic Technique.** Again, the rate of descent is checked by rounding out and reducing power. In the tail-wheel aircraft, however, the control column should be moved progressively back, increasing the attitude (angle of attack) as the speed decreases, and holding the aircraft off the ground. Too rapid movement of the control column causes the aircraft to balloon away from the ground, while too slow a movement allows the aircraft to sink onto its main wheels and bounce (para. 72). In a well-judged landing, a moment is reached when the aircraft can no longer be prevented from sinking onto all three wheels together; the control column is then fully back. Brakes can be used when all the wheels are firmly on the ground; initially slight brake should be used, increasing the effort as the speed falls. A brief brake check should always be carried out as soon as the aircraft is firmly on the runway so that more time is available for emergency action in the event of brake failure.

Three-Point Landing

54. Three-point landing is usual for tail-wheel aircraft and has the following advantages:—

(*a*) The touch-down speed is the lowest possible (little more than the stalling speed) and therefore the landing run is the shortest possible.

(*b*) The brakes may be used early in the landing run.

(*c*) There is less danger of the aircraft nosing over if the brakes are used too fiercely or the wheels enter soft ground.

Wheel Landing

55. A wheel landing is one in which the main wheels are placed on the ground before the tail wheel. This type of landing differs from the three-point landing in that, once the aircraft is flying just above the ground, it is not held off and the main wheels are placed gently but deliberately on the ground. The wheel landing may on occasions be preferred to the three-point landing because:—

(*a*) The change of attitude when landing is less and there is no hold-off, so judgment is easier.

(*b*) It has certain advantages when landing across wind (para. 69).

(*c*) It provides a safer means of landing heavily laden aircraft.

The main disadvantage of the wheel landing is that the speed is higher at the moment of touch-down, making for a longer landing run.

GENERAL CONSIDERATIONS WHEN LANDING

Effects of Flap on Landing

56. In all aircraft the use of flap shortens the landing run owing to the increased drag and lower touch-down speed. In tail-wheel aircraft it also :—

(*a*) Reduces the period of float and the distance covered while floating.

(*b*) Reduces the touch-down speed for a three-point landing because the stalling speed is reduced.

Use of Brake

57. With nose-wheel undercarriages maximum braking may be used when necessary, as there is no danger of nosing over. Pilot's Notes state whether continuous or intermittent applications of brake should be used during the landing run. The following handling points should be observed when using brakes :—

(*a*) If runway distance permits, delay the use of brakes until the speed has fallen to a low figure. On high-performance aircraft with anti-skid brakes, it is recommended that an interval of ten minutes should elapse between landings involving heavy braking. If the period of taxying after such a landing also involves heavy braking, the interval should be 20 minutes before the brakes are again used harshly. Failure to observe this precaution can result in a fire at the brakes.

(*b*) On a wet runway or muddy ground the wheels tend to lock. This occurs easily when high-pressure tyres are used. As the greatest braking effect is obtained with the wheels on the point of locking, the brakes should be applied very carefully. If the wheels are locked the braking effort is severely reduced since the aircraft "skis" along with virtually no friction between the wheel and ground. When anti-skid units (para. 58) are fitted to the braking system the brakes can be applied fully at any speed without the wheels locking, but on wet or slippery runways their effectiveness is still reduced, perhaps drastically.

(*c*) With a tail-wheel undercarriage, if it is necessary to use brakes when the speed is high they should be applied for short periods at frequent intervals with the control column held right back. This method reduces the risk of nosing over.

Anti-Skid (Maxaret) Braking System

58. As stated in para. 57 (*b*) the maximum effect from wheel brakes is obtained when the wheels are only just able to turn. When anti-skid units are fitted the brakes can be put hard on and the automatic unit then regulates the amount of pressure at the brakes ; pressure is applied until the wheels start to skid, some pressure is then automatically released and is thereafter governed so that maximum braking efficiency is obtained. Evidence that the maxaret unit is in operation is shown by violent fluctuation of the individual pointers on the brake pressure gauge. With this system the landing run is much reduced. However, the brakes must be applied only after touching down as the maxaret system will only operate once the wheels are turning. The very effective braking obtained from this anti-skid system should not be abused, and normal braking should be used whenever possible to prolong the life of the brakes and tyres.

Braking Propellers

59. In some propeller-driven aircraft, the main braking after landing is done by reverse thrust. Immediately after landing, the propeller pitch is changed to the braking setting, and power is increased. This produces a large reverse thrust which slows the aircraft smoothly and rapidly, thereby considerably increasing tyre life and brake wear. In multi-engine aircraft the initial throttle opening should be made carefully to check that all propellers have reversed before increasing power further. A safety device prevents the use of reverse thrust during flight.

Special Notes for High-Performance Aircraft

60. In many operational and more advanced aircraft the wing loading and the stalling speeds are comparatively high. To keep the landing run as short as possible, the recommended approach and runway threshold speeds given in Pilot's Notes cannot always be made high enough to give the same margin of control as do corresponding speeds for aircraft of lower wing-loading. In turbulent conditions and when even small amounts of *g* are applied, this margin is further reduced and special care must be taken on the final turn-in when turbulent conditions prevail. Since the runway threshold speed may be only ten knots above the stalling speed a smooth round-out is essential to avoid a *g* stall followed by a heavy landing. A smooth round-out is particularly necessary for this reason when at high landing weight and/or when swept-back

wings are used. Power must not be reduced too soon or too quickly ; if it is, the rate of descent increases rapidly. In general, the greater the power required to maintain the approach path and speed, the slower should be the rate at which power is reduced during the round-out. If the rate of descent increases for some reason, a coarse checking movement of the control column can easily cause a *g* stall. The approach path should be comparatively flat, so that a small round-out is needed ; steep approaches should not be made unless a higher speed is used to allow for the more pronounced round-out.

Engine Handling

61. On many gas-turbine engines, particularly the earlier turbo-jets and all turbo-props, there is a limit to the rate at which the throttle can be opened from an initially low r.p.m. without causing surging due to overfuelling. It must also be remembered that on these engines there is an inherent delay of some seconds between the moment of opening the throttle and the time when the power is high enough to be of appreciable use ; thus the necessity for power increases must be anticipated and all corrections to the approach path should be made in good time to allow for the lag in engine response.

Length of Landing Run

62. With the trend towards high wing-loadings and hence higher landing speeds it is becoming increasingly important to use all of the available runway. The aim should be to touch down near the beginning of the runway. A touch-down made farther up the runway is usually due to faulty judgment.

Procedure after Landing

63. The runway should be cleared as quickly as possible. To avoid obstructing other aircraft, the aircraft should be taxied well clear before starting the after-landing checks specified in Pilot's Notes. Stopping on the runway or "back-tracking" can only be done after requesting permission to do so from air traffic control.

Types of Approach and Landing

64. **Engine-Assisted Approach.** The use of power on the approach enables the I.A.S. and the rate of descent to be adjusted safely over a wide range, but very low, flat approaches using a high power are undesirable. Other characteristics of the engine-assisted approach are :—

(*a*) By using selected power settings it is possible to regulate the angle of approach despite varying wind strengths.

(*b*) The change of attitude when rounding out is small compared with that for a glide approach.

(*c*) The use of power reduces the stalling speed and thus a lower approach speed can be used.

and in propeller-driven types only :—

(*d*) The increased slipstream gives more rudder and elevator control than when no power is used.

65. **Glide Approach.** The salient features of the glide approach are :—

(*a*) As there is no power with which to adjust the rate of descent, a high standard of accuracy is required to judge the position on the base leg at which to close the throttle.

(*b*) The correct gliding speed is maintained by use of the elevator ; the nose of the aircraft must be lowered in turns to maintain that speed.

(*c*) The rate of descent is high and the angle of descent may be steep, particularly in advanced trainers and operational aircraft. If descending into a strong wind the rate of sink may appear alarmingly high.

(*d*) A considerable change of attitude is made during the round-out. *Therefore, to avoid g stalling, the round-out must be started earlier and at a higher I.A.S. than for an engine-assisted approach.*

66. **Flapless Landings.** Pilot's Notes advise on the speeds and technique used for a flapless landing. Flapless landings should be practised occasionally to ensure that the pilot is able to use this method after failure of the flap mechanism. This type of approach and landing is also recommended when landing in a strong wind, particularly if the aircraft has a low wing-loading. On high-performance aircraft the low drag with the flaps up often causes some difficulty in losing speed after having turned onto the final approach ; to cross the runway threshold at the recommended speed, adjustments to the speed should be made in good time to avoid arriving at the runway at too high a speed. A flapless approach and landing differs

in on the main wheels but does not bounce, the throttle should be closed and the control held central or slightly forward to prevent the aircraft from ballooning off the ground, then brought back as the speed falls off. Particularly on smaller aircraft with a high-powered piston engine, large bursts of engine should not be used to cushion a bad bounce since the high torque and low speed may easily result in a *torque stall* and a strong and sudden wing drop. (The high torque imposes a rolling moment, in the opposite direction to propeller rotation, which cannot be countered by the ailerons at low I.A.S.)

(*b*) *Holding Off Too High.* This causes a stall and a heavy drop onto the runway and may be accompanied by a dropping wing. If the aircraft is stalled high the correct action is to open the throttle to gain speed and increase the rudder and elevator effectiveness with the stronger slipstream. If the stall is accompanied by a wing drop, this can be stopped by using the rudder to yaw the nose away from the dropping wing. The remarks on torque stalls apply equally in this case.

(*c*) *Ballooning.* If this occurs the control column should be moved forward slightly to prevent the aircraft gaining more height and, when the surplus has been lost, the aircraft should be landed as from a bounce.

In all cases of doubt it is advisable to go round again.

73. **Nose-Wheel Aircraft.** In nose-wheel aircraft a bad landing is normally a heavy landing due to one of the following causes :—

(*a*) Too coarse a round-out from a steep approach, resulting in *g* stall.

(*b*) Too low an airspeed over the boundary, often due to no allowance being made for a higher landing weight.

(*c*) Raising the nose too high so that, on touch-down, the rear of the aircraft strikes the ground. Landing on the main wheels and the nose wheel simultaneously may also lead to structural damage, as the nose-wheel oleo is not designed to withstand landing impact loads.

Going Round Again

74. To go round again the throttle should be opened smoothly to the power required (slam accelerations should be avoided), the aircraft steadied, the undercarriage raised, and the I.A.S. allowed to increase to the recommended figure. In some aircraft the flaps can be raised at the same time as the undercarriage ; in others it may be necessary to raise flaps first ; and in yet others it is necessary to wait until enough height has been gained to offset the pronounced sink (Pilot's Notes advise on the correct procedure). In the last case, if full flap has been used on the approach, it may be expedient to raise the flaps to the maximum lift position at the same time as the undercarriage is raised, the remainder being raised when a safe height has been reached. This action quickly reduces the drag without seriously affecting the lift, and results in an improved climb. On aircraft with nose-wheel undercarriages, if it is decided to overshoot after touching down, the nose wheel should be on or just clear of the runway when opening the throttle. If an attempt is made to overshoot when in a marked nose-up attitude, *e.g.* as when using aerodynamic braking, the rate of acceleration is much reduced owing to the high drag and in extreme cases, particularly with swept-wing aircraft, the aircraft may not be able to climb away. Once the decision to overshoot has been made, *particularly at night or under I.F. conditions*, no further height should be lost, and the aircraft should be held in a steady climb while overshoot actions are being completed.

Wheel Shimmy

75. Some aircraft are prone to encounter wheel shimmy while moving on the ground. Shimmy can be identified by vibration and noise which may vary between being temporary and mild to prolonged and severe. The tendency to shimmy is a property possessed by a freely castoring wheel assembly such as a nose wheel or tail wheel assembly ; most assemblies are provided with damping devices to eliminate the trouble, but shimmy may still occur under certain conditions, *e.g* faulty tyre pressure or oleo inflation. When shimmy occurs the aircraft should be slowed down, or stopped if necessary until the trouble disappears. If strong shimmy occurs during the take-off, the take-off should be abandoned if the pilot is certain of being able to stop in the length of runway remaining ; if the pilot is not certain the take-off should be completed in spite of the shimmy.

Gas Turbine Engines—Flame-Out when Landing on Wet Runways

76. When landing on runways which have a substantial covering of water, the nose wheel throws up a heavy spray which can cause a flame-out, particularly in aircraft having wing-root intakes or side intakes situated behind the nose wheel.

77. When landing on a runway on which large puddles of water are present the following precautions should be observed:—

(*a*) Not more than one aircraft on the runway at a time.

(*b*) After touch-down the nose wheel should be held off the runway as long as possible.

(*c*) Roller landings should be avoided; the decision to go round again should be made before touch-down.

▶Mechanics of the Landing Roll

78. When considering the mechanics of the landing roll the first point to appreciate is that the greater part of the roll is covered at a relatively high speed. When the aircraft is slowing down the time spent in each equal band of speed (100 to 90 kts., 90 to 80 kts., etc.) is roughly the same, but the distance covered is proportional to the mean speed of the band (95 kts., 85 kts., etc.). This is shown diagrammatically in Fig. 6.

Effect of Wing Lift

79. During the landing roll the aircraft is retarded by aerodynamic drag and the use of brakes. The aerodynamic drag, excluding that due to the propellers, varies as the square of the airspeed. The lift from the wing is also proportional to the square of the airspeed. Thus, at the higher speeds, the weight on the wheels is considerably reduced, as shown in Fig. 7. However, for a given coefficient of friction between tyre and runway, the maximum retarding force which the brakes can provide is proportional to the weight on the wheels (in modern aeroplanes the brakes are sufficiently powerful to lock the wheels at most speeds on a wet surface), and it follows that the retarding force of the brakes is reduced at high speed. If, for convenience, it is assumed that the coefficient of friction between the tyre and the runway remains constant, the relative contribution of aerodynamic drag and braking drag to the total retarding force would be as shown in Fig. 8. Since, in practice, the

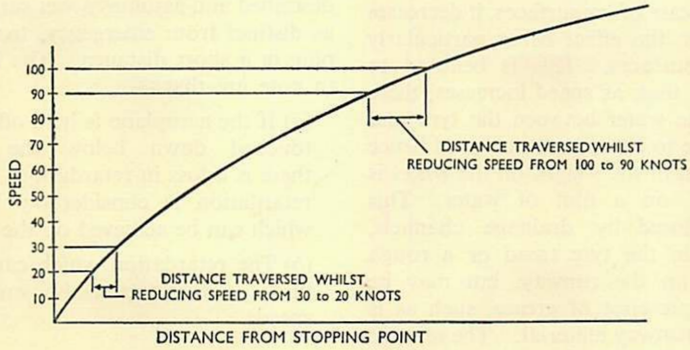


Fig. 6. Comparison of Distances Traversed whilst Reducing Speed

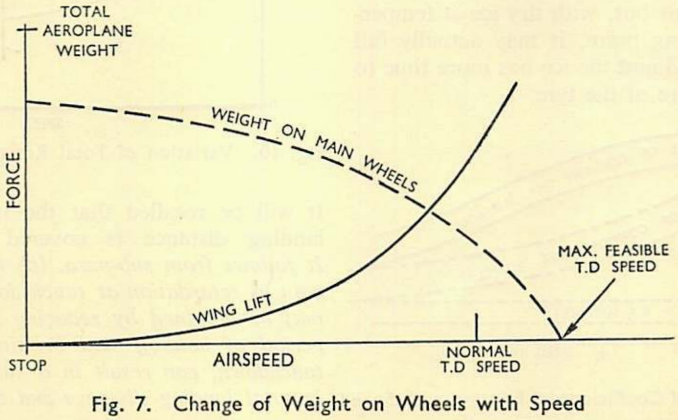


Fig. 7. Change of Weight on Wheels with Speed

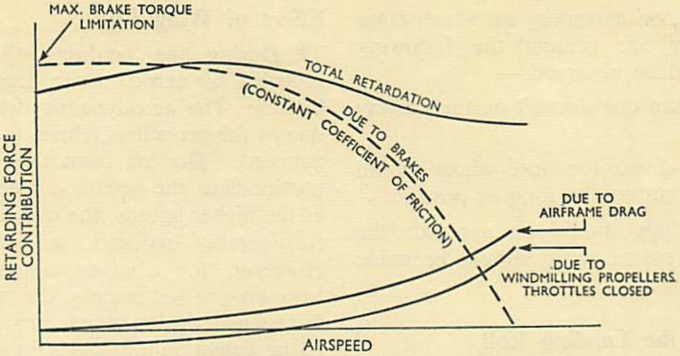


Fig. 8. Contributing and Total Retardation Forces

effect of speed is normally to reduce the coefficient of friction, as explained below, the retarding force is, in most cases, still further reduced at high speeds.

Effect of Speed on the Coefficient of Friction

80. In Fig. 9 the variation of the coefficient of friction with speed is shown. It will be seen that, except in the case of icy surfaces, it decreases as speed increases, the effect being particularly marked on wet surfaces. This is believed to be due to the fact that, as speed increases, there is less time for the water between the tyre and the runway surface to be squeezed out and hence a larger proportion of the weight on the wheel is carried, in effect, on a film of water. This effect can be reduced by drainage channels, such as grooves in the tyre tread or a rough granular surface on the runway, but may be increased by the presence of grease, such as is exuded by certain runway material. The reasons for the apparent reduction in the coefficient of friction at high speeds on dry surfaces are more complex and less readily explained. In the case of wet ice the coefficient of friction is practically constant but, with dry ice at temperatures near freezing point, it may actually fall as speed is reduced and the ice has more time to melt under pressure of the tyre.

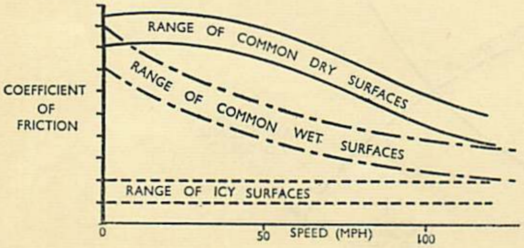


Fig. 9. Variation of Coefficient of Friction with Speed

81. **Summing the Effect of Wing Lift and Speed.** The typical variation of retardation with speed, taking all the above factors into account, which can be achieved on a landing, is shown in Fig. 10. The airborne portion from the threshold is shown as a broken line and the ground portion as a solid line. The retardation is the total retardation taking into account the effects already described and assumes a wet surface and normal, as distinct from emergency, technique for stopping in a short distance. The important points to note are that:—

(*a*) If the aeroplane is held off the runway and touched down below the normal speed, there is a loss in retardation, because airborne retardation is considerably lower than that which can be achieved on the ground.

(*b*) The retardation which can be achieved at high speeds is appreciably smaller than at low speeds.

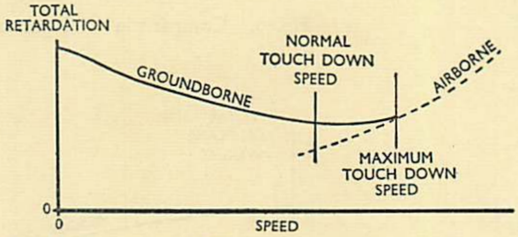


Fig. 10. Variation of Total Retardation with Speed

It will be recalled that the larger part of the landing distance is covered at high speed. *It follows from sub-para. (b) that quite a small gain in retardation at touch-down speed, such as may be obtained by reducing to a minimum the period of hold-off and braking immediately on touchdown, can result in a substantial reduction in total landing distance and can be worth more* *than a large improvement in retardation at low speed.* Since a braking parachute is most effective at touch-down speed, it is particularly helpful in reducing landing distance.

Best Stopping Technique

82. In general, the best technique for stopping an aeroplane in the shortest distance is to touch down at the earliest practicable moment after crossing the threshold with as much weight as possible on the main wheels and to apply maximum braking immediately. (This does not, of course, imply that the threshold should be crossed with less than a safe margin of height.) Even on an extremely slippery surface such a technique, if the aeroplane characteristics permit its proper implementation, will give better results than reliance on ordinary "aerodynamic" braking down to a low touch-down speed or to a low nose-wheel lowering speed. It has been explained that most of the landing distance is covered at a fairly high speed and that, although the retardation from the wheel brakes is poor at high speeds, the increase so provided over that obtainable with air drag alone is valuable. Where the aeroplane is fitted with propellers which can be reversed or which produce high aerodynamic drag after touch-down, the importance of not delaying the touch-down is considerably increased as these devices are most effective at high speeds; they should not be used before touch-down except in extreme emergency, and even then only with the greatest care. As regards high aerodynamic drag before touch-down it should be noted that propeller discing drag is frequently controlled by an undercarriage switch and cannot, therefore, be used before touch-down.

Factors Limiting Early Use of Brakes

83. With non-automatic brakes it is easy to burst tyres if the brakes are applied when the aircraft is travelling at high speed on a dry or "patchy" runway. On a really slippery runway, however, the risk of bursting tyres is small and, subject to the maintenance of directional control, it is generally preferable on this type of surface to lock the wheels if there is any serious doubt about ability to stop within the runway. It should, however, be noted that there is some evidence that the improvement in braking on an icy surface from sanding of the surface is less with a locked wheel than with a rolling wheel. Although the coefficient of friction is at its highest when the wheels are nearly, but not quite locked, it is impossible to maintain this condition with an ordinary braking system and any attempt to do so may result in reduced braking efficiency. (On some older types of aircraft the brakes may tend to fade towards the end of a long run if used hard from touch-down. For such aircraft guidance on the best technique should be obtained from Pilot's Notes.)

84. Consideration of such factors as avoiding wear on the brakes and tyres will, of course, influence technique in day-to-day operations. It is stressed that departures from the best technique for stopping in a short distance are only admissible if the distance available under the prevailing conditions is clearly not critical.

Methods of Increasing the Weight on the Wheels (Aeroplanes with Nose-Wheels)

85. In the case of aeroplanes with soft nose-wheel suspensions it is advantageous to push the control column forward as soon as the nose-wheel is on the ground. This increases the weight on the wheels and also increases the directional control of the nose-wheel which can be useful when landing on a slippery runway in a crosswind since it reduces the need for differential braking, use of which decreases the total retardation available. Care should, however, be taken when using such a technique to avoid the situation arising in which the reduction in wing lift is offset by excessive transference of weight to the nose-wheel and tailplane. In aircraft with hard nose-wheel suspensions, the weight on the main wheels can be increased by placing the nose-wheel on the ground, applying the brakes, and then easing the control column right back. This technique gives the advantages of low angle of attack reducing wing lift, and a down-loaded tailplane, both of which increase the weight on the wheels.

86. The use of reverse pitch, by disturbing the flow over the wing, provides a most effective way of getting weight onto the main wheels, even if only idling power is used. Once the propellers have gone into reverse there is little to be gained from using the elevators to put the weight onto the main wheels. In which case they should be used in accordance with instructions for minimizing control snatch.

87. Unless overriding circumstances such as unusual weather conditions, or such special features of the aircraft as inter-connection of the throttles and flaps, make it unwise or impossible,

full flap should be applied well before crossing the threshold both in the interests of permitting a lower safe approach speed and reducing the float if the speed at the threshold should prove to be too high. In this connection it should be noted that flap handling practice in the air ought to remain consistent, as experience has shown that larger variations of approach speed occur where the flap handling is varied with the prevailing conditions. The optimum point for the application of full flap naturally varies with the type of aircraft because of differences in the sensitivity to the use of full flap.

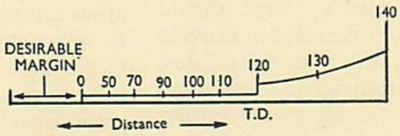
Landing Techniques

88. As a good general rule, unless a runway is patently much longer than will be required, an aeroplane should always be handled, at least down to the point of touch-down, as if the runway length were critical. This does not imply however, that a reduction in target threshold speed or height below the normal safe and comfortable minima is acceptable. Fig. 11 illustrates this point and also shows the penalty incurred by the use of "aerodynamic" braking, *i.e.* holding the nose-wheel high instead of lowering it and applying the brakes. Fig. 12 shows the effect of various techniques and conditions on landing distance.

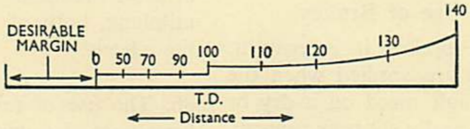
Threshold Speed and Height

89. In emphasizing the importance of using a suitable target threshold speed, it must be remembered that there may be a need to vary the target approach and threshold speeds with weight. Where the landing weight is substantially below the average it is advantageous to adjust the target speed accordingly. If constant approach power settings are used regardless of weight, the threshold speed is increased as weight is reduced. This can result in the aeroplane taking a longer distance to stop at low weights than at high weights.

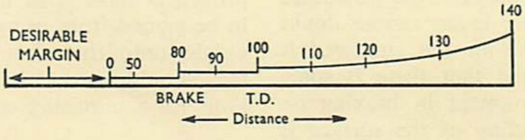
90. While the existing minimum landing distance requirements aim to make some provision for different surface conditions, this can only be achieved within certain limits. It follows that a pilot must take special measures to ensure safety where extreme conditions are known to exist. For example, if a flight is planned to an aerodrome where wet ice conditions are liable to exist, an additional margin of distance above the minimum will usually be required if adequate safety is to be ensured. Similarly, when only the minimum landing distance is available a pilot should abandon an attempt to land if his height and airspeed at the threshold are appreciably in



TOUCH DOWN EARLY AND BRAKE EARLY



TOUCH DOWN LATE BUT BRAKE IMMEDIATELY



TOUCH DOWN LATE. HOLD NOSEWHEEL HIGH
UNTIL 80 KNOTS THEN LOWER AND APPLY BRAKES.

Fig. 11. Total Landing Distance of a Typical Aeroplane from an Approach Speed of 140 knots Showing the Effect of Different Techniques

excess of those intended. It is emphasized that each knot of excess airspeed has, in the case of a typical large piston-engined aeroplane, about the same effect on landing distance as 10 feet of excess height. They both add about 1·8 per cent. to the total landing distance.

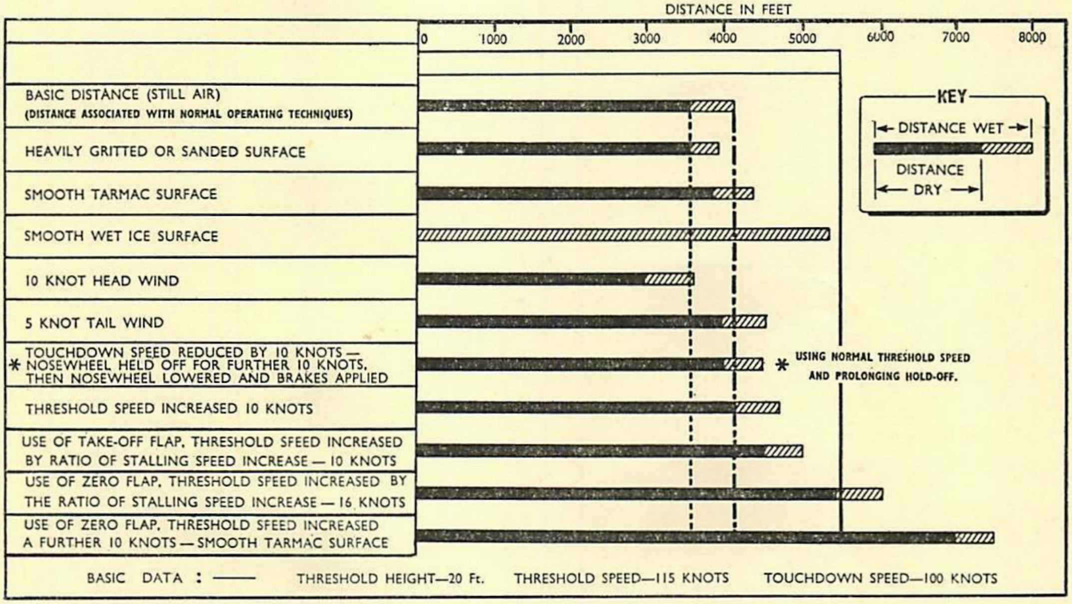


Fig. 12. Effect of Various Techniques and Conditions on Landing Distance ◀

(*A.L.* 4, *Mar.* 58)

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