PART 4: SECTION 3

CHAPTER 2

FORCED LANDING TECHNIQUES AND OTHER LANDING EMERGENCIES

General Considerations

1. A forced landing is a landing which was not allowed for in the flight plan. When an emergency arises which necessitates a descent and landing, two courses of action are open to the pilot :—

(*a*) Abandoning the aircraft.

(*b*) Landing at the nearest airfield or on the best available terrain.

2. Pilot's Notes for the smaller high-performance aircraft sometimes advise against an attempted landing and recommend abandoning the aircraft unless the selected area is known to be satisfactory in all respects. Since landing on an unprepared surface would probably entail severe damage to the aircraft and possible injury to the crew, it may be wiser to abandon the aircraft in such an emergency to ensure the safety of the crew. However, the types of emergency that can be encountered are many and varied and occasions are possible on which there is no option but to land.

3. If there is no alternative but to land the procedure to be adopted depends on the circumstances prevailing at the time of the emergency, the main considerations being :—

(*a*) Whether or not engine power is available.

(*b*) Altitude.

(*c*) Aircraft type and its flying and handling characteristics.

(*d*) Weather.

(*e*) Nature of the terrain.

(*f*) Day or night, *i.e.* the amount of light.

(*g*) Whether to land with the undercarriage raised or lowered.

4. Sound airmanship can either obviate the need for a forced landing or, if one does become necessary, give the pilot the greatest chance of completing it successfully. Such points of airmanship are :—

(*a*) Thorough pre-flight planning, including a review of the weather expected for the flight, a check of the main features of the terrain over which the aircraft is to fly, the radio aids available at each stage, and the correct action to take if diverted.

(*b*) Conscientious preparation of the aircraft for flight.

(*c*) Maintaining a mental idea of position during flight, and the sensible use of radio aids to verify this.

(*d*) Noting the type of terrain over which the aircraft is flying so that, if a forced landing becomes necessary, as little time as possible need be spent in searching for a suitable landing area.

5. The decision as to the best course of action must be made quickly, and the frequent practice of emergency drills and procedures gives the pilot the best chance of instinctively doing the correct thing should the emergency arise. If an emergency arises the captain should not hesitate to ask for aid by radio, using whatever degree of priority is deemed necessary.

Position of the Undercarriage

6. The aircraft captain must make the decision as to whether or not to lower the undercarriage for a forced landing in a particular emergency. Several factors must be considered in making the decision and Pilot's Notes and Flying Orders may also give guidance.

(*a*) If the aircraft has a retractable tail-wheel undercarriage, then for a landing on open countryside the wheels should be kept retracted. If this is not done there is a risk of nosing over and the aircraft coming to rest in the inverted position.

(*b*) If the aircraft has a retractable nose-wheel undercarriage, experience shows that in many cases it is best to lower the wheels for a landing on open countryside. By so doing the risk of injury is minimized, since the initial impact is cushioned by the undercarriage and the fuselage may be held clear of the smaller obstructions immediately after touch-down. Full brake can be applied giving a high deceleration. If the ground is very rough, loss of any or all of the undercarriage legs, although causing perhaps greater damage to the aircraft, also results in a faster deceleration.

7. When landing with the wheels raised the impact forces are transmitted directly to the aircraft and crew ; also a landing in this configuration tends to lead to faulty approach speeds—either too high or too low. Especially with aircraft having swept wings the nose-high attitude on touch-down causes the nose to "slap" down on impact, and this is a possible cause of spinal injuries. Lowering a nose-wheel undercarriage ensures that the heavy impact when the nose whips down is cushioned by the nose wheel and the landing impact is absorbed by those parts of the aircraft intended for this purpose.

8. On nose-wheel aircraft with straight wings the landing on open country can usually be made safely with the wheels retracted, provided of course that the external stores have been jettisoned ; however, there is nothing to prevent the captain from deciding to lower the wheels if he considers that this would be an advantage under the circumstances.

9. When landing any type of aircraft with the wheels retracted the aircraft should be flown onto the ground as slowly as possible, the vertical rate of descent at the moment of touch-down being kept to a minimum. It is better to touch down slightly fast than to stall the aircraft and allow it to drop to the ground with a higher rate of descent.

Types of Forced Landing

10. The various types of forced landings can usually be considered under two main headings:—

(*a*) Forced landings with power.

(*b*) Forced landings without power, or with only partial power.

The first deals with situations where the pilot has power available to control the aircraft down to the point of touch-down on a chosen landing area. The second deals with instances where the pilot has to rely on his judgment and skill alone because, if any power is available, it is only enough for him to make relatively small corrections to his descent path and not enough for a normal circuit and landing.

FORCED LANDINGS WITH POWER—DAY

Introduction

11. The circumstances of a forced landing with power may vary from the relatively simple condition of landing in good weather on a strange aerodrome to landing in poor weather in a restricted area such as a field in open country.

Normal Diversion

12. Landing at a diversion airfield should present no problem, since full landing instructions can always be obtained from Air Traffic Control using the common airfield frequency, the command guard frequency, or if necessary, one of the distress frequencies. If radio contact is impossible, circuit information can be obtained from the signals square. For aircraft having a long landing run the main item to check is the runway length.

Forced Landing Away from an Operational Airfield

13. A pilot finding himself in difficulties should make the decision to carry out a forced landing while sufficient fuel and time remains. If possible, thirty minutes should be allowed for the complete procedure although less time is acceptable under favourable circumstances. Once the decision has been made the pilot should inform all occupants of the aircraft of his intention so that each can carry out the crash actions applicable to the type of aircraft, and he should at once set about finding a suitable landing area. The method of selecting that area and keeping it in sight in bad weather, the positioning for the final approach, and the decision whether or not to land with the undercarriage lowered (paras. 6 to 9) are all decisions which call for sound airmanship, common sense, and judgment. The factors which influence these decisions are discussed in the following paragraphs.

14. **Visibility.** In good visibility, the pilot need only reduce speed sufficiently to allow himself enough time to assess the suitability of fields in the immediate vicinity. In bad visibility, however, he must reduce speed to the minimum consistent with safety, *i.e.* adopt bad-weather low-flying procedure if this has not already been done ; otherwise it will be extremely difficult to select a field and then keep it in view.

15. **Choice of Landing Area.** In North-West Europe, and particularly in the United Kingdom, there are many disused airfields with runways which are quite suitable for an emergency landing. If such an airfield has a white bar painted beneath the normal white cross displayed on the runway threshold, this indicates that it has been inspected within the last six months and found to be fit for emergency use. However, a pilot should still make a thorough low-level inspection to determine the suitability of the surface. A landing should not be made on an airfield with the letters "EX" painted in white on

the runway, as this denotes that explosives are stored there. If a disused airfield is not available, a field or other suitable area having the following characteristics should be chosen :—

(*a*) A suitably long run, preferably into wind.

(*b*) The surface should be reasonably smooth, hard, and free from obstructions.

(*c*) The field should not have a pronounced slope.

(*d*) The leeward boundary should not have any high obstructions. (It is a further advantage if the windward boundary is also unobstructed so that, if necessary, the aircraft can go round again.)

(*e*) The ideal field should be near some means of communication such as a road or a house.

If a field is inspected and found to be not wholly suitable, the pilot then has to decide whether he should seek a better one, or whether the fuel state or other emergency demands an immediate landing on that field.

16. **Preliminary Technique.** After a field has been selected, a bad-weather circuit (paras. 17 to 21) should be flown to make a preliminary inspection of the field and to locate it relative to prominent landmarks. This is a necessary precaution in case the field becomes lost from view. An inspection run at a slow safe speed, using partial flap, should then be flown. This entails an approach as for a normal landing (the pre-landing checks being completed except for the lowering of the undercarriage), and then at the lowest safe convenient height the aircraft should be levelled and flown across the field at the slowest safe cruising speed. The path of the inspection run should be slightly to one side of, and parallel to, the intended landing path. This inspection run enables the pilot to :—

(*a*) Check the intended approach path for obstructions, etc.

(*b*) Thoroughly examine the surface of the intended landing path.

(*c*) Assess the drift.

While flying over the field, the compass reading should be noted as a basis for course steering for subsequent circuits of the field. If visibility is bad, conspicuous landmarks should be noted to enable the field to be found if temporarily lost. An accurately timed circuit (discussed in para. 17) should be made if the field cannot be kept in view all the time. When the windward boundary of the field has been reached, the aircraft should be climbed to circuit height or as high as the existing weather conditions permit, whichever is the lower. A further inspection run can be made if required and if the fuel state and other considerations permit.

Bad-Weather Circuit Procedure

17. When circumstances demand a forced landing (whether on an airfield or elsewhere) in poor visibility and in the absence of runway approach aids, a timed and accurate circuit should be flown around the selected landing area so that, if it disappears from view during certain stages of the circuit, the pilot can be certain of seeing the landing area ahead of him on the final approach. This type of circuit (Fig. 1), accurately flown, can be used to place any type of aircraft in a suitable position from which a landing can be made ; any errors of alignment need not be more than about 100 yards.

18. **Airspeed.** The airspeed for flying in reduced visibility is given in Pilot's Notes and should be used for this type of circuit. While the speed used on the downwind leg is not critical, both turns must be made at the same I.A.S.

19. **Rate of Turn.** It is important to the accuracy of final alignment with the runway that accurate Rate 1 turns are flown using the same airspeed for each turn.

20. **Drift.** Drift should be assessed before starting the circuit. To compensate for wind effect during the two turns, about three times the angular drift allowance for the airspeed should be made on the downwind leg.

21. **Final Approach.** After about the first 135° of the final turn, the landing area or airfield approach lighting should be visible. (If necessary, clear-vision panels should be used.) The touch-down point can then be kept in view by a gently curved final approach. If conditions are such that contact is not made at this stage, the full 180° turn should be completed and the runway heading ± drift allowance steered ; the speed should be reduced to the correct approach speed and the pre-landing checks completed.

Final Approach and Landing

22. When the decision to land has been made, the final circuit should be started. The necessary pre-landing checks should be done even if a wheels-up landing is intended, and the canopy, escape hatches, and external stores should be jettisoned as appropriate. The harnesses of all

the occupants must be tight and locked, and crash positions adopted. The approach should be made using the short-landing technique, which involves crossing the threshold of the field at the lowest safe approach speed with power on and full flap lowered. When in a safe position and near the ground the throttle should be closed and, assuming that the wheels are retracted, the touch-down made in a tail-down attitude. If the wheels have been lowered, brakes should be used to stop the aircraft as soon as possible.

FORCED LANDINGS WITHOUT POWER—DAY

Introduction

23. The reliability of modern engines makes forced landings without power an infrequent occurrence, but since engine failure is possible, pilots must know what such a landing entails and develop the necessary skill to complete it ; this skill can only be obtained by frequent practice. A forced landing necessitated by partial engine failure should be treated similarly to one caused through total engine failure.

24. The procedure for a power-off forced landing depends on the type of aircraft and the flight circumstances when engine failure occurs, *i.e.* it will depend on whether a forced landing is necessitated by :—

(*a*) Engine failure at low altitude, *i.e.* during or immediately after take-off, or when flying very low with insufficient surplus speed to gain height, or when flying beneath low cloud.

(*b*) Engine failure at higher altitudes.

(*c*) Failure of one or more engines on a multi-engine type, when the pilot is unable to maintain or gain height and has no alternative but to land.

Engine Failure During the Take-off Run

25. Engine failure during the take-off run in the case of twin- and multi-engine aircraft is discussed in Section 2, Chapter 2, paras. 32 to 38. For single-engine aircraft, if the remaining distance is insufficient to bring the aircraft to rest before encountering rough ground or obstructions the pilot must decide whether or not to raise the undercarriage. If external fuel tanks are carried

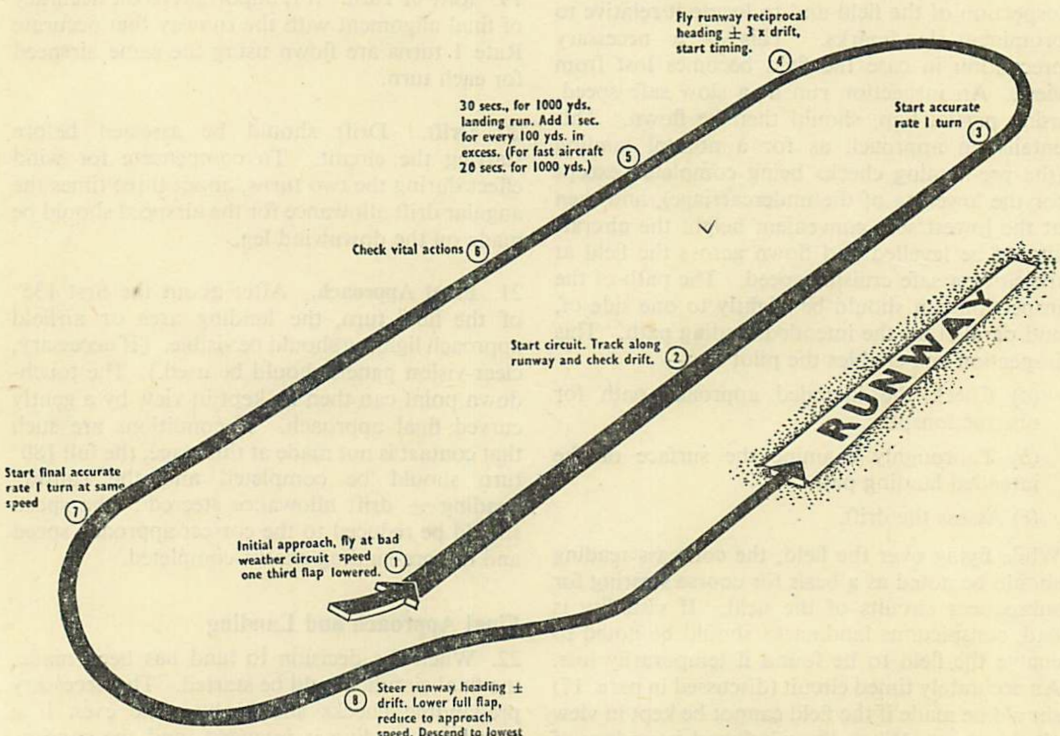

Fig. I. Bad Weather Timed Circuit

every effort should be made to jettison these ; if there is no time then, depending on the circumstances, it may be preferable to leave the wheels down. If the aircraft collapses onto the external tanks there is a serious risk of fire.

Engine Failure After Take-off

26. (*a*) For twin- and multi-engine aircraft see Section 2, Chapter 2. On single-engine aircraft, if total failure occurs while the speed is lower, or only slightly more, than the gliding speed, the throttle should be closed, care being taken to maintain a safe gliding speed and a landing made virtually straight ahead. While, at low speed and altitude, it is seldom possible or safe to turn back to the airfield, moderate changes of heading can be made to avoid obstacles or turn into wind.

(*b*) On most turbo-jet aircraft the rate of acceleration is such that, shortly after becoming airborne, the airspeed is considerably higher than the gliding speed. In these types of aircraft it is possible to convert the speed into a higher altitude and lower speed so that it may be possible to regain the airfield after engine failure. This procedure should be attempted only if the speed is substantially higher than the gliding speed ; the speed should not be allowed to fall below this speed until the aircraft is on the final stages of the approach.

Engine Failure at Low Altitude

27. Engine failure when low flying has almost the same implications as stated in para. 26, except that there will probably be excess speed available which can be exchanged for a higher altitude and lower speed thus giving the pilot a greater choice of landing area. If the speed is high, it is possible on aircraft fitted with fully automatic ejection seats to gain enough altitude to permit abandoning the aircraft.

Engine Failure at Altitude

28. Unlike engine failure on take-off, where very rapid action is called for, engine failure at a reasonable height gives time to assess the situation. There may also be time to find the cause of engine failure and even to remedy it and to select from a number of possible landing areas.

29. If partial power is still available, a forced landing without power should be made in case the failure becomes complete. In such circumstances it would therefore be most unwise to try to reach a distant airfield. However, if an airfield were reasonably near and the intervening area no worse for a forced landing than that below the aircraft when the failure occurred, *e.g.* over the sea, it would be logical to attempt to reach that airfield.

30. **Possible Causes of Engine Failure.** When an engine fails, the pilot should try to locate the cause of failure and, if possible, rectify the fault after first gaining height by using any excess speed and then selecting and turning towards the chosen landing area. Some common causes of engine failure are given below ; all these causes, with the possible exception of carburettor icing and some forms of mechanical defect, usually result from poor airmanship :—

(*a*) *Jet Engines.*

- (i) Fuel shortage.
- (ii) Mishandling of fuel system.
- (iii) Mechanical defect.

(*b*) *Piston Engines.*

- (i) Fuel shortage.
- (ii) Ignition switches knocked off.
- (iii) Mishandling of fuel system.
- (iv) Mishandling of mixture control.
- (v) Overheating.
- (vi) Carburettor icing.
- (vii) Mechanical defect.

Wind Velocity

31. A mental note of the wind velocity at take-off should always be made and checked during flight by reference to indications on the ground (*e.g.* smoke, but not from moving objects such as trains). This knowledge can be of great value if the need for a forced landing arises.

Selection of the Landing Area

32. When making a forced landing without power it should be realized that there is only a limited time in which to search for a suitable field, and an inspection run cannot be made. Therefore the habit of searching periodically for suitable landing areas should be cultivated. The frequency of such surveys depends on the altitude at which the aircraft is flying.

33. The requirements for a suitable landing area are :—

(*a*) A large enough area with a suitable surface.

(*b*) The approach path should be free from high obstructions, since these reduce the effective landing run by increasing the distance between the boundary of the field and the touch-down point.

(*c*) The area should be level, but slight gradients can be tolerated. (It is difficult to judge the topography of an area from the air. Indications of the direction of slope are the position of rivers, lakes, and marsh ground relative to the area, and the light and shade cast on the ground by the sun when it is low on the horizon.)

(*d*) Secondary considerations are that the landing area should be near some means of communication so that assistance can be quickly obtained and salvage work facilitated.

34. **Surface of the Landing Area.** The ability to recognize various types of surface comes with experience. A guide to these is given below in their order of suitability for forced landings with the undercarriage up.

Surface	*How Recognized*
Stubble ...	... An even buff colour, regular lines being visible from low altitudes.
Grassland	... Usually a mottled green, varying from dark green if low-lying and damp to brownish green if dry or burned by the sun.
Firm sand	... An even sandy colour without dark spots or lines. On a beach, the sand a few yards from the water's edge is usually suitable.
Young grain	... A rich, dark uneven green.
Crops ...	... Regular lines will be visible at low altitudes.
Young root crops	Similar to grain crops, but regular lines will be visible at a greater height.
Ploughed land ...	The colour varies with the nature of the soil, no vegetation being visible. If furrows are visible, land along them if the undercarriage is not retractable.
Ripe grain	... Colour varies with the type of crop from buff to golden brown. If there is any wind, movement of the grain will appear in waves flowing in the direction of the wind.
Heathland	... A mottled, brownish green colour, usually in large areas on high ground. It is often covered or partly covered with gorse or heather. The surface is usually pock-marked with rabbit holes, etc.
Marshland	... Dark green, with still darker green spots or patches. Scattered pools of water or streams can generally be seen in the vicinity.
Rocky uneven ground	As for heath land, plus rocks of various colours.
Forest ...	... The colour depends on the time of the year and the types of trees, but recognition is easy.

A landing on any of the above surfaces, except forest or rocks, should usually entail little risk of injury to the crew. However, if the aircraft has a fixed tail-wheel type undercarriage, the hazard of nosing over must be appreciated and the landing area selected accordingly. In general, stubble and grassland are the only surfaces suitable for safe landings with a fixed tail-wheel undercarriage.

Personal Equipment

35. (*a*) Parachute harness should, if possible, be unlocked so as not to impede escape. The safety harness should be tightened to give maximum security.

(*b*) Helmets, oxygen masks, and gloves should be worn for protection against injury and fire, with all unnecessary leads disconnected and securely stowed. Goggles or visors should be lowered as an additional safeguard.

Selection of the Landing Path

36. Having chosen the landing area it is necessary to select the best landing path. The choice of this depends on : wind direction, length of landing run, gradient, and obstructions. Ideally the landing path should be into wind, but if a considerably longer run can be obtained by landing across wind, then this should be chosen. If the wind is light it may be better to land uphill and downwind. A landing path which entails an approach over obstructions should be avoided, since the effective landing run will be curtailed. The best landing path will be one combining the best of the above features.

Circuit and Approach

37. Unless the circuit and approach are correctly judged the forced landing will probably not be successful. Only by conscientious practice can the required skill and judgment be acquired and kept at a high level. Unless the pilot is familiar with the characteristics of his aircraft in an engine-off forced landing, an appreciable element of luck enters into whether or not it will have a happy conclusion.

38. The circuit and approach pattern varies widely between types of aircraft and is primarily decided by the rate of descent on the glide and the gliding speed. The gliding angle may be disconcertingly steep when full flap is lowered and the round-out may therefore have to be started in good time to avoid a *g* stall.

39. The forced landing pattern for any type of aircraft can be built up on what are known as key points. Fig. 2 illustrates an example of an imaginary pattern based on three such keys. If the altitude at the time of the emergency was lower than, say, the high key, then the pilot would have to position his aircraft so that the medium key was reached as the first check on the pattern. If unable to attain the altitude for the medium key then the low key point would have to be used.

40. When practising forced landings to establish a circuit pattern, the pilot should remember that there should be a margin in hand to allow for varying wind strengths. To this end the low key point should be sited so that the final approach to the touch-down point can be made by using a wide turn (for little or no wind) or a more direct course (for a strong wind).

41. When manœuvring in the circuit pattern it should be remembered that the ground elevation should be subtracted from the indicated altitude (QNH) to give the altitude above the ground.

42. At all times the landing area should be kept in view and all turns should be towards the field ; violent S turns on the final stages of the approach should be avoided, since the loss of height in such turns may be excessive and it becomes more difficult to judge the touch-down point ; further, the danger of an inadvertent stall is increased. By establishing a definite base leg and low key point the pilot can adjust the approach by turning early if undershooting or delaying the turn if too high.

43. While on the downwind and base leg portions of the pattern it is important to keep at the optimum distance from the touch-down point. To assist in this, the pilot should note the amount by which the wing or some other portion of the airframe overlaps the landing area while on the down-wind leg, particularly when at the correct medium key position. To ensure that the correct distance is maintained at the low key point, a reference point on the windscreen or nose can be used.

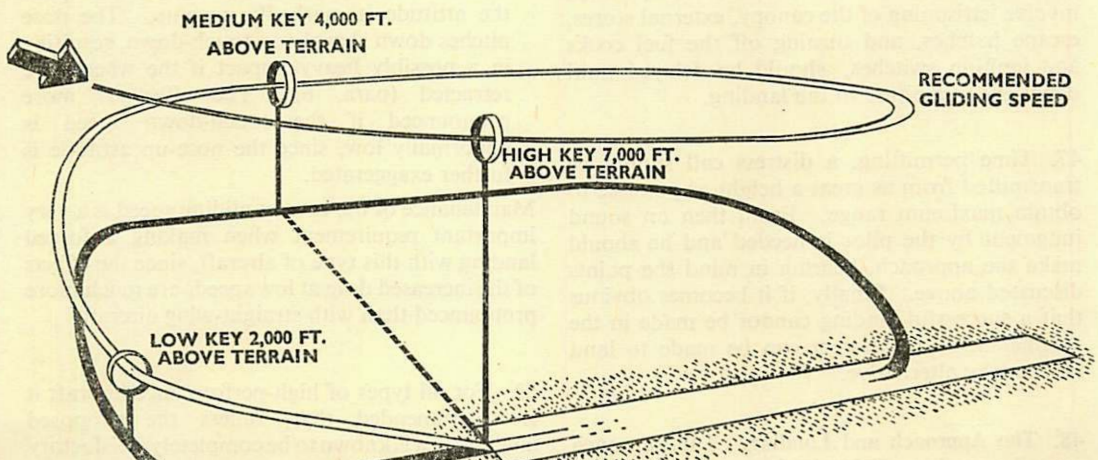

Fig. 2. Typical Forced Landing Pattern showing Key Points

44. **Use of Propeller Controls.** On piston-engine aircraft having a constant-speed propeller, drag can be reduced and a flatter glide path achieved by selecting the minimum r.p.m. (coarse pitch) position. However, on certain types, high engine r.p.m. are needed to change pitch and little will be gained by using the propeller control. The difference to the angle of glide is considerable on high-powered aircraft having multi-bladed propellers, and the use of minimum r.p.m. greatly increases the gliding range of the aircraft. However, this pitch alteration may upset the pilot's judgment if he has been in the habit of practising forced landings with the propeller control at a fine setting in readiness for the overshoot. The propeller pitch setting should therefore be governed by circumstances.

Typical Forced Landing Procedure

45. When the engine fails, any speed in excess of the best gliding speed should be converted to height. On slow aircraft this increase will be small but on fast types several thousand feet may be gained. Unless there is height to spare the pilot should then choose the landing area and quickly plan and begin the circuit before trying to locate and remedy the cause of the failure. At the same time any other occupants should be ordered to prepare for a crash landing.

46. The pre-landing actions should be done as early as possible. These include deciding on whether to lower the undercarriage, propeller lever as required, and the harnesses tightened and locked back. The crash actions, which involve jettisoning of the canopy, external stores, escape hatches, and turning off the fuel cocks and ignition switches, should be delayed until definitely committed to the landing.

47. Time permitting, a distress call should be transmitted from as great a height as possible to obtain maximum range. From then on sound judgment by the pilot is needed and he should make the approach, bearing in mind the points discussed above. Finally, if it becomes obvious that a successful landing cannot be made in the original field, an attempt can be made to land in a nearby alternative.

48. **The Approach and Landing.** The approach must be made sufficiently fast to ensure good control right up to the time of touch-down ; with no power available the speed should be not less than that for a normal glide approach. On swept-wing aircraft approach speeds greater than the normal approach speed are recommended in Pilot's Notes ; the excess speed can be used to prolong the glide safely if undershooting, and if the approach has been correctly judged the surplus speed is not necessarily an embarrassment if the surface is reasonably level and free of the more solid obstructions. Excess height can be eliminated by a slight dive, or on some types of aircraft by side-slipping.

49. If the landing area is partially obstructed and a collision is possible, the touch-down point should be judged so that the aircraft covers the greatest distance before colliding with the obstacle. In this way the impact is minimized and the risk of injury reduced.

Special Notes for High-Performance Aircraft

50. All the considerations in the preceding paragraphs apply equally to jet and piston-engine aircraft. However, with some jet aircraft a number of additional factors arise.

51. **Swept-Wing Aircraft.** Two additional points arise when considering aircraft having swept wings and high wing loadings :—

(*a*) If the final glide approach is made at an appreciably lower speed than that recommended, the rate of descent and gliding angle are greatly increased.

(*b*) When touching down at the normal speed the attitude is markedly nose-up. The nose pitches down sharply on touch-down, resulting in a possibly heavy impact if the wheels are retracted (para. 6). The effect is more pronounced if the touch-down speed is abnormally low, since the nose-up attitude is further exaggerated.

Maintenance of the correct gliding speed is a very important requirement when making a forced landing with this type of aircraft, since the effects of the increased drag at low speeds are much more pronounced than with straight-wing aircraft.

52. For all types of high-performance aircraft it is recommended that, unless the proposed landing area is known to be completely satisfactory in all respects, the smaller types having touch-down speeds of above about 120 knots should be abandoned rather than landed after an engine failure. Pilot's Notes give advice on this point.

FURTHER CONSIDERATIONS FOR BOTH TYPES OF FORCED LANDING

Preparation of the Aircraft

53. Before a forced landing the captain should, where applicable, consider the following points:—

(*a*) *Jettisoning of Stores.* All external stores should be jettisoned if the aircraft is over open country; bombs should be dropped safe and the bomb doors closed.

(*b*) *Jettisoning of Fuel.* Unless the aircraft is, or has been, on fire, surplus fuel can be jettisoned from some types of aircraft and the jettison cocks then closed. Fuel should be jettisoned early to allow as much time as possible for the fuel that has settled on the fuselage and mainplanes to dry, otherwise the sparks caused by friction on touch-down may cause fire. Drop-tanks should be released, whether containing fuel or not.

(*c*) *Fuel Cocks, Battery, and Ignition Switches.*

(i) If committed to a power-off forced landing, all fuel cocks and (where applicable) ignition switches should be turned off. The battery should be kept on only for as long as its services are required to operate items such as the radio or certain instruments. It should be switched off before the touch-down is made. All these precautions are necessary to reduce the fire risk. If the battery operates the fire extinguisher system, then of course it should be left on.

(ii) If engine power is available, the battery switch should be treated as above and, when the aircraft has come to rest, the fuel and ignition must be turned off; however, if circumstances permit and the actions can be carried out without prejudice to the touch-down, the fuel and ignition may be turned off just before the touch-down is made.

(*d*) *Hatches.* All lower hatches should be secured and the appropriate upper side escape hatches opened or jettisoned.

(*e*) *Loose Equipment.* Loose items of equipment in the fuselage should be either jettisoned or securely stowed.

(*f*) *Personal Considerations.* As a precaution against injury and fire all crew members should wear their helmets, oxygen masks, gloves, and goggles or visors for extra protection, all unnecessary leads being securely tucked away; whenever possible inter-communication with the pilot should be maintained.

(*g*) *Cockpit Hoods or Canopies.* These items should be dealt with in accordance with the advice given in Pilot's Notes. Damaged hoods or canopies should not be jettisoned unless the aircraft is to be abandoned immediately. The aerodynamic characteristics of a damaged hood or canopy may have altered appreciably, and therefore when jettisoned may cause loss of control through striking and damaging the tailplane or fin.

Aircraft Handling

54. If engine power is available a short landing should be made, touching down as early as possible from a final approach made at the lowest safe speed of the aircraft. If only partial power is available, it should be used to make a safe landing in the chosen area, the approach speed being a little higher than for a short landing. If no power is available, a high degree of judgment is required and the final approach should be made as for a normal glide approach.

Use of Flaps

55. Full flap should normally be used in the final stages of the approach unless the aircraft has characteristics which make this unwise, *e.g.* rapid loss of speed and very steep descent. Use of flap during a powered approach increases the drag and more power is therefore required for a given speed; this in turn gives the added advantage of better control. Use of power also reduces the stalling speed.

Use of Engines

56. On propeller-driven aircraft with two or more wing-mounted engines, the engines should be throttled right back just before the touch-down and, if practicable, the ignition switched off, because a propeller which is windmilling in fine pitch is less likely to break off and strike the fuselage than when the engine is under power. The risk of a propeller breaking off and striking the fuselage is probably greater if it is feathered, as the blades, being edge on, are more liable to break off than to bend. However, if a crash landing is necessitated by engine failure, the propeller of any failed engine should not be unfeathered before touch-down. In these circumstances the captain should, where possible, send the crew to suitable crash positions aft, and if the aircraft has dual controls he should, if practicable, complete the landing in the seat farthest from the feathered propeller.

Forced Landing without Power

57. The factors discussed up to this point apply in principle to all types of aircraft, but there are additional important considerations which are normally more applicable to turbo-jet types. These concern the effect of the loss of certain ancillary services following complete engine failure and the subsequent effect on the handling of the aircraft during the descent and landing. These considerations are :—

(*a*) *Loss of Heating Services.* Loss of cabin heating and demisting services, if operated by the failed engine, may lead to heavy misting and icing on both the inside and outside of the canopy during a descent from high altitude. The use of the external liquid de-icer and electrical windscreen de-icer would ease the problem, since both should still work satisfactorily. Direct vision panels will also be valuable. If necessary, a rag soaked in glycol, which should be carried for the purpose, can be used to remove ice from the inside of the canopy.

(*b*) *Powered or Power-Assisted Flying Controls.* When powered or power-assisted flying controls are used, engine failure and the subsequent use of an emergency manual flying control system may result in severely limited manœuvrability even at low speeds, and comparatively very high stick forces may be necessary to position the aircraft for the forced landing. Pilot's Notes give guidance on the characteristics of the aircraft in these cases, and the recommendations made should be carefully studied. The circumstances governing the forced landing, the amount of control remaining and, possibly, the time for which it is available, will dictate whether the aircraft should be abandoned or whether a forced landing can be attempted.

(*c*) *Flight Instruments.* The endurance and charge state of the aircraft battery or the standby battery for the operation of gyro instruments during a descent from considerable height through a great vertical thickness of cloud may be limited, and the approximate time for which it is available should be known by the pilot. Some aircraft have a sufficient reserve of battery power to keep the V.H.F. set, electrical flight instruments, and the pressure-head heater operating for at least thirty minutes, but on others the time is considerably less ; Pilot's Notes may give guidance on this point.

Landing

58. Immediately before the touch-down the battery isolating switch should be turned off, unless by so doing the fire extinguisher system is rendered inoperative (see Pilot's Notes). On nose-wheel aircraft, at the moment of impact the nose will pitch down sharply followed by rapid deceleration and possibly further violent shocks until the aircraft finally comes to rest. It is important not to relax until the aircraft has stopped. Fire extinguishers should be operated at the first opportunity after touch-down. Immediately the aircraft has stopped, the occupants should leave through the recommended exits as quickly as possible and clear the aircraft on the upwind side. Not until the fire risk has passed should the crew return to collect the emergency equipment.

GLIDE CONTROLLED DESCENT

General Procedure

59. Provided he is within gliding range of a suitable airfield, the pilot of an aircraft that has had complete engine failure at height should be able to carry out a successful forced landing on the airfield if there is a cloudbase of at least 3,000 feet and good visibility below. The basic procedure involves homing to overhead, making a spiral descent through any cloud, and completing a glide approach and landing. The pilot should :—

(*a*) Transmit a distress message giving the height and type of aircraft. From this information the most suitable airfield within gliding range can be alerted to take control of the aircraft.

(*b*) Glide at the optimum range speed and home to overhead. If the cause of the forced landing is a flame-out, an attempt to relight should be made when at the proper height.

(*c*) When overhead, increase speed by 50 knots and start a Rate 1 descending spiral. The excess speed is required for adjusting position in the circuit after breaking cloud.

(*d*) Transmit every half-minute, giving heading and height. From these transmissions, control can inform the pilot of any adjustments to the orbit to allow for the wind effect and bring the aircraft to the correct position on the downwind leg.

(*e*) When below cloud, position the aircraft for a glide approach and landing. The flaps should be lowered only when it is clear that the runway is within reach ; if there is a tendency to overshoot, surplus height can be lost by diving slightly and accepting the higher touch-down speed.

60. This procedure should prove effective for a cloudbase of 3,000 feet or more, but only by constant practice can pilots and controllers achieve a high standard of accuracy. During practice a small amount of flap should be used to offset the effect of idling thrust.

ENGINE FAILURE IN OR ABOVE CLOUD

General Considerations

61. If the engine fails while flying in or above cloud, the main considerations are :—

(*a*) Type of surface over which the aircraft is flying.

(*b*) Height of the cloudbase.

(*c*) Type of cloud.

(*d*) How long the instruments will remain reliable after engine failure.

62. The aircraft should be abandoned unless the following requirements can be met :—

(*a*) The cloudbase is such that the pilot will have time, after breaking cloud, to judge the suitability of the ground for a forced landing and then to select a field and position the aircraft, or to abandon the aircraft if the terrain is unsuitable.

(*b*) The pilot can control the aircraft during the descent, allowing for the degree of turbulence in the cloud and the time for which the gyro instruments will remain reliable. If the engine (piston or jet) is still windmilling it will normally provide sufficient suction to operate suction-operated instruments ; if there is no suction they will be unreliable after about two to three minutes. On aircraft with electrically-driven gyro instruments, provided the batteries are well charged, the instruments will be completely reliable for the descent even from a considerable height. If a complete electrical failure occurs they will be reliable for only two to three minutes.

FORCED LANDINGS AT NIGHT

Introduction

63. At night, landing emergencies fall into the following categories :—

(*a*) Engine failure soon after take-off.

(*b*) Engine failure at altitude.

(*c*) Landing at a strange airfield after being diverted or lost.

Engine Failure After Take-off

64. The actions to be taken after engine failure on take-off at night are the same as those for daylight, with the addition that the landing lamps should be switched on so that the ground can be seen and major obstructions avoided.

Engine Failure at Altitude

65. Following engine failure at height by night an attempt at a forced landing can seldom be justified. The aircraft should be headed for open country and abandoned while sufficient height remains. The only normal exceptions to this rule would be :—

(*a*) If there were exceptional conditions of moonlight and visibility, the area beneath was known to be suitable, and obstructions could be clearly seen.

(*b*) If the failure occurred within gliding distance of an airfield, the runways of which could be seen. (If in radio contact all available lighting aids should be requested ; if not, firing a red Very light at any point would indicate a state of emergency, and the airfield would be kept clear by Aerodrome Control.)

Landing at an Unknown Airfield

66. A landing at an unfamiliar airfield presents no problem, particularly if in radio contact and landing instructions are obtained. If this is not possible, however, the necessary information can be obtained from inspection of the lights and the movements of other aircraft. If the aircraft is flown along the runway at 600 to 800 feet above the ground and a green signal cartridge is fired, aerodrome control will know that radio contact cannot be made and priority for a landing will be given by appropriate lamp signals. The length of the flarepath can be assessed by allowing 300 feet between flares on a goose-neck flarepath, and the same distance between the runway contact lights of the Mk. 2 and 3 lighting systems. When high intensity uni-directional runway lighting is used, the lights viewed from the direction of approach are 100 feet apart, but when viewed looking downwind along the runway, as after take-off, the visible lights are 300 feet apart.

OTHER LANDING EMERGENCIES

Landing Without Brakes

67. Many aircraft need the assistance of brakes to stop in the length of runway available unless the runway is very long and/or the wind is strong. If the brake system has failed a safe wheels-down

landing is possible in suitable conditions. The main factors to be borne in mind are :—

(*a*) If possible divert to an airfield having the longest run into wind. It may be necessary to jettison all external tanks and stores in case the wheels have to be retracted.

(*b*) If the area is suitable, land on the grass on the emergency side of the runway to obtain better deceleration.

(*c*) Cross the runway threshold at the correct speed and touch down as early as possible.

(*d*) On landing, hold the nose wheel high off the ground to obtain the maximum drag, and stop the engine. Additional drag may be obtained by opening the airbrakes, bomb doors, and canopy on the approach. The canopy should, whenever possible, be open to prevent possible jamming in the closed position should the aircraft be damaged in overrunning the airfield.

(*e*) In light winds use the runway giving the best combination of length of run and uphill gradient.

(*f*) If it becomes obvious that the landing space will be inadequate, the wheels should be retracted. This will normally entail the operation of some override device.

68. If a pilot considers that he will be unable to stop, wheels down, in the space available, he should land with the undercarriage down and then raise it at a suitable distance from the end of the runway.

Landing with a Burst Tyre

69. To land with a burst tyre, the pilot should make a normal wheels-down landing unless Pilot's Notes for the type advises otherwise. The landing should be made on the runway, and after the touch-down the wing on the burst tyre side should be held up with aileron. Differential use of engines assisted by judicious use of brake may be necessary to minimize the resultant swing after the burst tyre has settled firmly on the ground.

Crash Landing on an Airfield

70. If it becomes necessary to land with the wheels up at an airfield, the landing should normally be made on a runway and not on the grass. Less damage is incurred by landing on a runway and there is less risk of injury to the crew. A normal approach and touch-down should be made. With swept-wing aircraft it is important that the touch-down speed is not lower than the usual speed so as to avoid touching down in a marked nose-up attitude.

Landing with One or More Wheels Unlocked

71. If one main undercarriage leg fails to lower or lock down, the subsequent action depends on the circumstances, the type of aircraft, and the experience of the pilot. Some aircraft sustain least damage from a crash landing, others from a landing on the remaining wheels.

72. If committed to a landing when, for example, the port undercarriage leg has failed to lower or lock down, a normal approach and landing should be made. Immediately after touching down, stop the engine and turn off the fuel and battery, if this can be done without prejudicing the success of the landing. The ailerons should be used to keep the port wing up for as long as possible. When the wing eventually touches the ground the aircraft will swing in that direction, and careful use of the brakes should be made to control the severity of this swing as far as possible. The aircraft will always swing towards the unlocked wheel, therefore the landing path and runway should be chosen with this point in mind. The runway with the largest possible area of unobstructed ground, on the side towards which the aircraft will swing, should be used. The aircraft may travel as much as 400 yards away from the runway before stopping.

73. **Nose Wheel Not Locked.** If the nose wheel fails to lower or lock down the subsequent action depends on circumstances. The nose wheel may have been prevented from lowering by snagging on an obstruction in its wheel-bay—wherever possible the main wheels should be bounced on the runway in an attempt to free the nose wheel. If committed to a landing with the main wheels locked down and the nose wheel unlocked or up, a normal approach and landing should be made and the nose held well up for as long as possible ; as the speed falls off the elevator effectiveness decreases and the nose eventually settles on the runway ; at this point the brakes can be used to help to stop the aircraft. On certain aircraft (see Pilot's Notes) least damage will result from a crash landing. Immediately after touching down, stop the engine and turn off the fuel and battery. Less damage results from this type of emergency when a hard runway is used instead of grass.

74. When such an emergency arises, drop tanks and external stores should be jettisoned and the landing made with the canopy open or jettisoned. On certain aircraft it may be possible to use fuel in a tank sequence which will give an aft C.G., thus enabling the nose to be held up for a longer period.

75. Pilot's Notes and Flying Orders often give guidance on the best method of dealing with the emergencies detailed in paras. 67 to 74.

Landing on Wet or Icy Runways

76. Aircraft having high touch-down speeds and fitted with narrow-tread, high-pressure tyres must be landed with care on wet or icy runways. Because of the small area of tyre in contact with the runway, the wheels can be locked when using only a small amount of brake. Locked wheels result in a serious reduction in braking effectiveness, as the wheels, in effect, ski along the surface with very little friction.

77. If the runway is wet or otherwise slippery, consideration should be given to the advisability of diverting to a dry airfield or using a longer runway.

78. If there is no alternative but to land, then the brakes must be used with care since there may be no indication that the wheels have locked. Intermittent locking of either wheel is shown by brief, irregular crabbing movements. If anti-skid (Maxaret) brake units are fitted, even though wheel locking is eliminated, the amount of useful braking effect available can be seriously reduced.

79. In the absence of anti-skid units, the faulty use of brakes on a slippery runway can lead to the position in which the pilot, already using the maximum amount of useful braking, applies port rudder—and so more port brake—to change the heading of the aircraft slightly ; the effect of this action is to lock the port wheel and markedly *reduce* its braking effect, so causing the partially braked starboard wheel to become in comparison more effective and so cause a turn to starboard, not to port as expected. The natural tendency of the pilot is to apply still more port brake but this will only aggravate the situation. The correct action is to anticipate such a possibility and to release the brakes, maintaining the port rudder, and then gently re-apply the brakes.