PART 1 : SECTION 3

CHAPTER 12

ENGINE HANDLING

Introduction

1. The wide variety of gas-turbine engines in service, each having certain handling characteristics, means that the information in this chapter must be of a general nature. Pilots' Notes give precise details of engine handling for a particular aircraft and engine installation and cover both normal and emergency operation.

STARTING AND GROUND TESTING

Precautions

2. Whenever possible the aircraft should be headed into wind for all ground running. During prolonged ground running the aircraft should never stand tail to wind as hot gases may re-enter the air intakes and cause overheating. The aircraft should be positioned so that the jet-wake or any loose stones which may be thrown up will not damage other aircraft and/or buildings in the vicinity.

3. The surface of the ground ahead of the aircraft should be free of loose objects, and all personnel should be well clear of the intakes.

4. The ground starter batteries should be fully charged ; except in an emergency the aircraft batteries should not be used.

5. If the ground beneath the jet pipe becomes saturated with fuel after a failure to start, the aircraft must be moved to a new site before a further start is attempted, to reduce the risk of fire.

Turbo-Jet Engines

6. On most aircraft the starting sequences are fully automatic when once set into operation, but on some early aircraft individual stages may have to be operated by hand. In the latter case it is important that the hand stages are operated at the correct time in the sequence, otherwise the following faults may occur, the last two of which may cause overheating :—

(*a*) Failure to light up.

(*b*) Torching (flames from the jet pipe).

(*c*) Resonance (a characteristic rumbling as the engine lights up).

7. On most installations the L.P. and H.P. cocks and the L.P. booster pumps should first be turned on to allow a fuel flow to the engine-driven fuel pumps, and the throttle should be kept closed during the starting sequence. On some aircraft the starter sequence is inoperative unless the throttle is closed.

8. When cartridge turbo-starters are used the master starter switch and individual ignition switches should be off while loading is in progress. When the ground crew have indicated that it is safe to start, the master starter switch and ignition switch should be switched on and the starter button pressed. When the starter button is pressed the cartridge fires, and at the same time current is supplied to the igniters, and torch igniters (if fitted). The engine should then light up and accelerate to idling r.p.m.

9. When an electric starter is used the push-button should be held in for about two seconds and released. The starter sequence relay supplies first a low-voltage current to drive the starter-motor, then current to the booster-coils for the igniters, and torch igniters (if fitted), and finally a high-voltage current to the starter-motor which then accelerates the engine at a greater rate.

10. During the initial stages of acceleration the fuel pressure rises, and fuel is sprayed into the combustion chambers from the burners and ignited either by the torch igniters or the high-energy igniters. On some installations the fuel pressure may rise too rapidly and fuel may be discharged into the combustion chambers before the engine r.p.m. are high enough for a satisfactory light-up.

11. Pilots' Notes recommend that, when this is liable to happen, the H.P. cock should be closed or only half-open at the beginning of the starting procedure. This is to minimize the risk of resonance due to an excessive fuel/air ratio at the low initial r.p.m. and overfuelling, leading to surging and an excessive j.p.t.

12. After light-up, the engine speed increases under the combined influence of the turbine and the starter-motor. After about 30 seconds the

current to the starter-motor (when using electric starters) and igniter plugs is automatically cut off and the engine becomes self-sustaining.

13. The starting sequence should never be interrupted, *e.g.* by disconnecting the battery. If this is done, the starting sequence continues when the circuit is re-established, resulting in failure to start, flooding, and derangement of the system.

Failure to Start

14. If the engine fails to start, the H.P. cock should be closed as soon as this becomes apparent. If the cause is not apparent, one further attempt may be made before the fault is investigated. The most likely cause is a partially discharged starter battery which affects the igniters and, with electric starting, gives insufficient fuel pressure and cranking speed.

15. The engine should not be restarted until fuel has stopped spilling from all the fuel drains. This period also permits the starter to cool before the next attempt to start.

16. After a wet start (no light-up and loose fuel running from the jet pipe) incomplete combustion (torching) may be experienced on the next attempt. If this occurs, the H.P. cock should be turned off immediately and the engine allowed to run down and cool. The engine should be turned over by the starter with the H.P. cock, master starter switch, ignition, and priming pump isolation switches (when fitted) all off to blow accumulated fuel and vapour from the combustion chambers.

17. With cartridge turbo-starters, loose fuel can be cleared (the engine blown through) by firing another cartridge, keeping the master starter switch on, the ignition switch and H.P. cock off. If an internal fire is suspected the L.P. cocks and booster pumps must be turned off and the engine can be blown through to clear the fire, using the same method ; before another attempt to start, the engine should be examined as, if an internal fire has occurred, the engine may have been damaged.

18. Before the next attempt to start, the aircraft should be resited to avoid the possibility of the fuel-soaked ground catching fire ; the second start, if successful, is often accompanied by some degree of torching (even after the loose fuel has been drained or blown out), but this is temporary and soon disappears.

19. On some engines resonance may occur on light-up and can be recognized by the characteristic rumbling ; if this happens action should be taken as recommended in Pilots' Notes for the type. Usually a partial and temporary closure of the H.P. cock causes the resonance to disappear.

After Starting

20. After starting, allow the engine to idle for a brief period and check :—

(*a*) Oil pressure, if a gauge is fitted.

(*b*) Burner pressure, if a gauge is fitted.

(*c*) Jet-pipe temperature.

(*d*) All ancillary services.

Testing the Engine

21. Before carrying out any tests the throttle should be kept closed ; if a ground run of the engine is necessary, check :—

(*a*) r.p.m.

(*b*) Temperatures.

(*c*) Pressures.

(*d*) Operation of fuel-pump isolating valve.

(*e*) Operation of variable swirl vanes.

(*f*) Operation of the A.C.U.

These checks should be done on the runway, against the brakes, immediately before take-off. With more powerful engines it may not be possible to run up to take-off power against the brakes, and a check of the j.p.t. at cruising r.p.m. usually suffices. Apart from engine considerations, ground running should be kept to a minimum to conserve fuel.

22. **Reheat.** Unless the aircraft has a brake-boosted system or is securely chocked, it is usually not possible to test the reheat system on the ground as normal brakes are not powerful enough. If boosted brakes are fitted and/or the aircraft is securely chocked, reheat can be checked by opening the throttle through the gate to the REHEAT position. Check :—

(*a*) That reheat comes on within one to two seconds.

(*b*) That the eyelids position indicator indicates correct functioning of the variable area nozzle.

(*c*) That the hot-gas warning light is out.

(*d*) That the j.p.t. has not altered by more than 5° C. from that indicated under stabilized non-reheat full throttle conditions.

(*e*) When cancelling reheat, pause for at least one second at the normal full throttle position.

Operation of reheat on the ground should be kept to a minimum.

23. **Reheat Failure.** If the reheat fails, the throttle must be closed to the full throttle non-reheat position. If the j.p.t. exceeds the permissible maximum, the reheat temperature limiter cancels reheat automatically and closes the jet-pipe eyelids. The eyelids indicator, however, shows white (abnormal indication) until the throttle is moved out of the reheat gate.

Turbo-Prop Engines

24. **Introduction.** The basic starting precautions are the same as those for turbo-jet engines. Turbo-prop engines can usually be started either by compressed air or by a cartridge. The propeller must always be set to the minimum fine-pitch setting for the start ; this is done by the use of the unfeathering switch.

Starting by Compressed Air

25. In double-engine installations (*e.g.* Double-Mamba) usually one engine only can be started by compressed air; the second engine is started by the windmilling procedure detailed in paras. 26 to 29. The compressed-air line should be securely plugged in and the ground crew should keep clear of the hose whilst air is being supplied to the starter-motor. To start the engine the following sequence of operations is necessary (the instructions apply to either double or single engines) :—

(*a*) Set the Ground/Flight switch to FLIGHT.

(*b*) Check that the flight fine-pitch stop is set to NORMAL.

(*c*) Set the throttle to the GROUND IDLE position.

In double-engine installations set the engine selector to the engine to be started.

(*d*) Where necessary turn on the L.P. cock.

(*e*) Set the propeller to minimum or starting pitch by opening the H.P. cock and pressing the propeller starting pitch button, then closing the H.P. cock when at the fine-pitch setting. (In the Gannet installation the H.P. cock has three positions and should be OFF and the feathering/relight button pressed until the propeller blades have reached the fine-pitch setting.)

(*f*) Switch on the ignition, if a separate switch is provided. If applicable, the starter fuel pumps should then be switched on.

(*g*) Immediately before signalling for the compressed air to be turned on, open the L.P. and H.P. cocks and switch on the L.P. booster pump. (In some installations opening the H.P. cock turns on the L.P. cock automatically. In most aircraft the L.P. booster pump operates when the L.P. cock is opened.)

(*h*) In some engines the feathering/relight button serves as the ignition switch and, if so, this should be pressed and released *after* the H.P. cock has been opened and when the propeller starts to turn.

(*j*) When the engine reaches the correct r.p.m. prolonged running of the turbo-starter by compressed air must be avoided ; therefore if the engine does not light up within the stated time, signal for the air supply to be turned off and wait for a minute before attempting another start. The engine should light up and continue to accelerate to idling speed without adjustment to the throttle setting. At an engine speed (given in Pilots' Notes) somewhat lower than the idling r.p.m., the ground crew should be signalled to shut off the compressed-air supply.

(*k*) On some engines the ignition should be turned off after light-up if this has not been done automatically ; extra fuel is then made available to allow acceleration to idling r.p.m.

Starting Double Engines by the Windmilling Method

26. In double-engine installations, start the first engine and run it at the warming-up r.p.m. until the oil temperature reaches the correct figure. Then increase power to the r.p.m. recommended for starting the second engine by windmilling.

27. After ensuring that the throttle of the second engine is at GROUND IDLE, that the engine selector switch is off, and that the flight fine-pitch stop is at NORMAL, turn on the L.P. cock, L.P. pump, and H.P. cock.

28. Press the feathering/relight button and release it when the r.p.m. of the second engine reach the recommended figure (usually 1,500 to 2,000 r.p.m.). Check that the ignition light stays on. The engine should light up at the recommended r.p.m., but if the j.p.t. seems likely to exceed the limitations the H.P. cock should be closed, and the procedure repeated when the propeller is almost feathered.

29. When the second engine reaches ground idling speed, the first engine should be throttled back to the same speed.

Cartridge Starting

30. In double-engine installations either engine may be started first. Assuming that, initially, the propellers are feathered and braked, start in the following manner :—

(*a*) Set the Ground/Flight switch to FLIGHT and proceed as in para. 25, sub-paras. (*a*) to (*f*).

(*b*) Next select the cartridge, and select the appropriate engine, PORT or STARBOARD.

(*c*) Turn on the L.P. cock, L.P. pump, and H.P. cock.

(*d*) Press the cartridge firing button to initiate operation of the starting fuel and ignition systems and fire the turbo-starter cartridge. The button stays in until automatically released after a fixed interval.

(*e*) In double-engine installations, when the engine has started, set the engine selector switch to OFF/RELIGHT.

(*f*) The second engine may be started by the windmilling method described in paras. 26 to 29.

Failure to Start

31. During starting operations a careful watch should be kept on the j.p.t. A faulty start is shown by a rapid rise in j.p.t. at a rate which indicates that the maximum permissible figure is likely to be exceeded. If this happens the start should be abandoned by immediately closing the H.P. cock and switching off the ignition switch. If the engine fails to light up, close the H.P. cock and allow the engine to run down and stop before making another attempt.

32. To clear surplus fuel if the engine fails to start, it can be motored over by the compressed-air or cartridge starter, with the H.P. cock closed and ignition off, care being taken not to exceed the recommended r.p.m. for starting with compressed air. This will dry the engine out for another attempt to start. Ensure that all fuel drains have completed draining before attempting another start.

33. If a fire occurs in the jet pipe (owing to overfuelling) the H.P. cock should be closed and the engine kept turning by compressed air up to the maximum permissible r.p.m. for air starting.

Warming Up

34. When the engine is idling, check the oil pressure and the j.p.t. Check the operation of all the engine instruments. The warming-up r.p.m. must not be exceeded until the oil temperature has reached the recommended figure.

35. If the throttle is opened too rapidly during the warming-up period and the j.p.t. rapidly increased to the maximum permissible with little or no increase in r.p.m., it may be an indication that the engine has stalled. This can cause internal damage through overheating and the throttle should be closed immediately, to the ground idling position.

Testing the Engine

36. When the oil temperature has reached the desired figure, the throttle may be opened slowly to the flight idling gate.

37. All throttle movements *must* be made slowly (see para. 35). Engine acceleration up to the flight idling gate is poor and the greatest care must be taken not to stall the engine. Warning that the engine is stalling or is stalled is given by :—

(*a*) Vibration and excessive noise in the jet pipe.

(*b*) r.p.m. not following the throttle movement.

(*c*) A rapid rise in j.p.t.

38. If the j.p.t. shows signs of exceeding the maximum permissible, the H.P. cock should be closed. Any delay causes serious damage. With the throttle at the flight idling gate, check that the engine r.p.m. are correct ; the normal figure may not be obtained until the engine is thoroughly warm, and there may also be an increase in r.p.m. due to head wind.

39. The tail should be lashed to the ground if a high engine power is used on run-up. Check the constant-speeding r.p.m. at the intermediate setting: r.p.m. and torque-meter readings should be within their limits but may vary with air temperature and pressure. After completing the checks, slowly throttle back to the ground idling setting.

TAXYING

Engine Considerations

40. Rapid and unnecessarily frequent opening of the throttle should be avoided while taxying, as this can cause over-fuelling, and consequent rumbling and surging, together with rapid increases in j.p.t.

41. The initial response of the engine to throttle movement is slow, and considerable power may be necessary to start moving some of the larger and heavier types of aircraft ; once under way, however, most aircraft require little power for taxying.

42. Owing to insufficient airflow over the rudder during taxying, the brakes should be used for directional control ; this applies also to many turbo-prop aircraft. On twin-engine aircraft a combination of differential throttle and braking may be used, but the poor acceleration of these engines should be allowed for. Also, excessive use of the throttles causes the generators to cut in and out frequently ; as far as possible the r.p.m. should be set above the generator cut-in speed and taxying done on the brakes, with due regard to the possibility of brake overheating.

43. The idling thrust of a turbo-prop engine is high, and once the aircraft is moving it is possible to taxy with the throttle at the ground idling position. Throttle movements should be made slowly, and a careful watch maintained on the engine temperature during prolonged periods of taxying. When stationary for long periods the engine should be run at a higher r.p.m. (given in Pilots' Notes) to ensure even and adequate cooling of the engine.

44. Owing to the high fuel consumption at idling speeds, taxying time should be kept to a minimum and taken into account when planning a flight.

TAKE-OFF

Engine Considerations

45. When conditions make the use of the shortest take-off run essential, the throttle should be smoothly opened, against the brakes, to take-off power and the brakes then released. On many aircraft the brakes will not hold at take-off power, in which case they should be released at the recommended r.p.m., and the remainder of the power applied during the initial take-off run. Normally, however, the throttle can be opened smoothly to full power without recourse to braking.

46. Axial-flow engines may tend to stall or surge under cross-wind conditions owing to the uneven airflow into the intakes. If this happens while taxying or preparing to take off across wind the throttle should be closed. It may be necessary to turn the aircraft into wind before the engine responds to throttle movement satisfactorily. When the engine is running satisfactorily at a higher r.p.m., the aircraft should be turned back to the desired heading for take-off and the remaining power applied.

47. Pilots' Notes for some aircraft state that failure to achieve a specified j.p.t. at take-off power is an indication that the engine is not giving full thrust and that the take-off should be abandoned.

Turbo-Prop Engines

48. In turbo-prop installations the brakes should be applied after aligning on the runway and the engine r.p.m. carefully increased to the recommended figure. The brakes should then be released and power increased smoothly to the take-off figure. Overspeeding of turbo-prop engines may be experienced if the throttle movement is not made smoothly, especially under take-off conditions. The maximum torque of turbo-prop engines may be reduced as altitude or air temperature increases. With installations having an auto-j.p.t. control, the take-off power may be considerably reduced at very high air temperatures. On double-engine installations, if the maximum torque available is less than normal, the minimum speed at which the aircraft can be climbed away on one engine at full available power will be increased.

Reheat for Take-Off

49. The aircraft should be correctly aligned on the runway, the brakes applied and brake-boost selected. The throttle should then be opened slowly to the reheat position and, after checking for correct operation (see para. 22), the brakes should be released. Two types of failure are possible when using reheat :—

(*a*) **Failure to Light Up.** A failure to light up is apparent by the lack of audible indication. There may also be a drop of about 150° C. in j.p.t. caused by the opening of the variable-area nozzle without the ignition of the reheat fuel. If this happens the thrust without reheat is seriously reduced, in addition to the loss of reheat thrust. The take-off should be abandoned ; for this reason it is essential to check that the reheat is operating satisfactorily before releasing the brakes.

(*b*) **Failure on Take-Off.** If reheat fails during take-off, and it is decided to continue the take-off, the throttle must be moved immediately to the full throttle non-reheat position to restore the thrust to the normal take-off figure ; at the same time checks must be made on the position of the eyelids and also to see that the j.p.t. is not subnormal.

CLIMBING

Turbo-Jet Engines

50. If the correct climbing speeds are not used, and particularly if the speed is too low, the rate of climb is reduced. At the highest altitudes, unless the correct speed is used the aircraft will not climb at all. During an operational climb at the recommended r.p.m and airspeed, a careful watch should be kept on the j.p.t., which should not exceed the permissible maximum, the throttle being closed slightly if necessary. If it is not essential to climb at combat power lower r.p.m. should be used at the same recommended airspeed. The use of a climbing speed higher than that recommended, in an attempt to reduce the j.p.t., can have the opposite effect.

51. Under certain conditions some engines are prone to surge while climbing at the higher altitudes. With centrifugal engines the symptom of a surge is a muffled detonation in the engine ; the throttle should be closed slightly and/or the airspeed increased as a remedy. With an axial-flow engine there may be no audible warning before the surge, the first symptom being a loss of power or a flame-out. If this happens, close the throttle immediately ; if a flame-out has occurred close the H.P. cock as well. This type of surge occurs only if the climbing speed is lower than normal. If the climbing speed for some reason falls below the correct figure at high altitude, power should be reduced below the climb r.p.m. while the speed is restored by diving the aircraft until the correct speed is attained.

52. In spite of the B.P.C., the r.p.m. for a given throttle setting may tend to increase with increase in altitude. The throttle should therefore be closed progressively to maintain constant r.p.m. Some later types of engines have a reduced tendency for r.p.m. to creep with altitude.

Turbo-Prop Engines

53. In high air temperatures power is reduced considerably if an auto-j.p.t. control is fitted, thus affecting climb performance. For a moderate rate of climb the throttle should be set so that the j.p.t. is kept just below the limiting j.p.t. In an operational (max. rate) climb, having set the recommended engine r.p.m., the throttle should be adjusted so that the j.p.t. is kept just below the limiting j.p.t. for that condition. Oil-cooler shutters may require adjusting if the oil temperature seems likely to exceed the limit.

GENERAL HANDLING CONSIDERATIONS

Principles

54. The principles of gas turbine handling are determined by the fact that this type of engine operates best at a fixed throttle setting. Therefore the life of the engine is materially affected by the number and rate of accelerations. Malfunction of the engine is normally associated with acceleration or with operating conditions that differ widely from the normal. Devices such as the A.C.U., B.P.C., swirl vanes, etc., are incorporated primarily to assist the pilot in changing the thrust conditions. A malfunction of these devices should not prevent successful control of the engine provided that greater attention is paid to throttle handling and the preservation of a good flow into the compressor. At high altitudes gas-turbine engines become extremely sensitive to throttle movement and the range of throttle movement between idling and full power may be very small owing to :—

(*a*) The lower limit which is dictated by the higher idling r.p.m. required to provide adequate fuel pressure for combustion and/or for cabin pressurizing considerations.

(*b*) The upper limit dictated by the throttle position above which the r.p.m. and/or j.p.t. limitations are exceeded.

Flame extinction may occur if the throttle is opened too rapidly. A too rapid throttle movement results in a momentary increase in j.p.t. followed by a flame-out. If this happens, or if an engine is intentionally stopped in flight, the H.P. cock should be closed immediately. Although relighting is not practical on all types of engines, it is reliable on most types especially at the lower altitudes. Pilots' Notes give the detailed procedure to be followed after a flame-out, and general information on relighting is given later in this chapter. The normal starting system, using the engine starter, should not be used in relighting, as this may damage the engine.

Centrifugal Compressor Engines

55. Provided that throttle movements are made smoothly and not too rapidly, there is little risk of flame extinction at altitude, at any throttle setting. The higher the altitude the higher become the engine idling r.p.m., and the more sensitive the engine to throttle movement.

Axial-Flow Engines

56. If on opening the throttle the r.p.m. remain constant but the j.p.t. rises to the maximum permitted, the throttle should be fully closed

immediately, as this indicates surging or a stalled compressor. A slower throttle movement should then be attempted, a careful watch being maintained on the j.p.t. in case the stalled condition has not been eliminated.

57. Low engine r.p.m. should be avoided as much as possible. If for any reason the r.p.m. have been allowed to drop below the recommended flight minimum value, care must be taken when opening up again, because of the possibility of stalling the compressor. This applies especially on the approach when the airspeed is low and the aircraft is sinking in a nose-up attitude which may cause the airflow to stall on encountering the lips of the air intakes. Hence the importance of keeping the r.p.m. at or above the recommended value on the landing approach until the decision to land has been made.

58. Above about 3,000 feet the effect of the A.C.U. is reduced on some engines, and rapid acceleration of the engine causes over-fuelling and surging. Engine acceleration characteristics deteriorate progressively with altitude on such engines, and care is required when increasing power at high altitudes. In early Avon engines, at altitudes above about 35,000 feet, the engine should not be throttled below the r.p.m. at which the two-position swirl vanes in front of the compressor change to the closed position. If the r.p.m. fall below this figure the throttle must be fully closed and not opened again above 28,000 feet. During a descent with the throttle closed there may be an audible rumbling from the engine, accompanied by a slight increase in j.p.t. This is not harmful, but the j.p.t. becomes excessive if an attempt is made to open the throttle above 28,000 feet. The above effects may often be overcome by increasing the I.A.S. On later models of this engine progressively variable position swirl vanes are fitted and the throttle may be closed to the normal flight minimum and opened again regardless of altitude, care being taken to avoid excessive j.p.t. during acceleration.

59. **High-Altitude Surge.** High-altitude surge may occur at altitudes above 40,000 feet when flying at a low I.A.S. and high r.p.m. under very low temperature conditions. The risk of this type of surge can be avoided by using r.p.m. not higher than combat r.p.m. minus 100 r.p.m. for each 5° below −55° C.

60. **Top-End Surge.** Similarly, top-end surge can occur at high *g* at very high altitudes. If this occurs there may be a substantial drop in r.p.m. followed by a higher than normal j.p.t. Closing the throttle and diving to increase I.A.S. effects a return to stable conditions. Climbing at full power and at a very low I.A.S., or a *g* stall at extremely low temperatures, can cause this type of surge.

61. **Variable Position Swirl Vanes.** The action of progressively variable position swirl vanes, while having no noticeable effect on engine running, reduces compressor efficiency unless the vanes have reached the fully open position. The lowest S.F.C. is obtained only by operating with the swirl vanes fully open.

62. **Surge/r.p.m. Indicators.** Some aircraft have a surge/r.p.m. gauge ; when the pointer of the gauge is clear of the red sector on the dial full r.p.m. can be used. When the needle is in the red sector, r.p.m. should be restricted to the indicated figure. Under standard atmosphere conditions the needle will not enter the red sector at an I.A.S. greater than 230 knots at 36,000 feet.

Mechanical Failure in Flight

63. If the engine fails owing to an obvious mechanical defect the immediate action should be :—

(*a*) Close the throttle and H.P. cock.

(*b*) Switch off the L.P. pumps. If the failure is accompanied by a strong fire risk, close the L.P. cocks as well.

In twin-engine aircraft shed all non-essential electrical load and land as soon as possible.

Reheat Failure in Flight

64. If, within five seconds of selecting reheat, there is no response, cancel reheat. The failure may be accompanied by a drop of about 150° C. in j.p.t. and also a considerable loss of thrust. Then select reheat again. If there is still no response cancel the reheat, and if the eyelids position indicator shows black the flight can be continued without the use of reheat. If the eyelids remain open (indicator shows white) the flight can be continued, but the maximum obtainable power is greatly reduced.

Reheat at Altitude

65. At very high altitudes *burbling*, caused by uneven combustion, may occur ; and in extreme conditions the reheat flame may go out. Since the system functions best when the mass flow through the engine is greatest, a lower altitude and higher I.A.S. may be necessary before reheat relighting is successful.

Turbo-Prop Aircraft

66. In flight, the throttle should not be closed beyond the flight-idle gate, except when relighting. When the engine is constant-speeding normally in flight, all movements between the flight-idle gate and the take-off gate should be made smoothly ; there is a possibility of flame extinction if the throttle is closed suddenly. The r.p.m. should not normally fall below the constant-speeding r.p.m., but should they do so the propeller fines-off until stopped by the flight fine-pitch stop (F.F.P.S.) ; if this happens the stop should be disengaged, otherwise the propeller behaves as though it were a fixed-pitch propeller, *i.e.* any further reduction of power or airspeed leads to a reduction in r.p.m. and any rapid opening of the throttle may easily result in the engine stalling. Normal r.p.m. can be maintained by observing the I.A.S. and power combinations recommended in Pilots' Notes. When it is not practical to meet these conditions, *e.g.* as in stalling practice, the F.F.P.S. should be withdrawn either manually or by lowering the undercarriage. To prevent the propeller fining-off too rapidly and causing trim changes, one of the recommended I.A.S. and power combinations must be maintained before the F.F.P.S. is withdrawn.

67. **Engine Failure in Flight.** If the engine fails in flight, the reverse torque circuit automatically coarsens the pitch almost to the feathered position. To feather the propellers fully, the H.P. cock must be closed and the starting pitch button pressed until rotation has ceased.

68. In the case of suspected mechanical failure, the engine should be stopped by closing the H.P. cock and pressing the starting pitch button to feather the propeller.

69. **Suspected P.C.U. Failure in Flight.** If P.C.U. failure is suspected the I.A.S. and power should be set at the figures recommended in Pilots' Notes and the F.F.P.S. set to EMERGENCY to lock the stop so that it cannot be withdrawn when the undercarriage is lowered. In double-engine installations, the faulty engine should be stopped and the flight continued on the other. On the approach, with reduction in airspeed, the r.p.m. should be kept, as far as possible, at intermediate r.p.m. After touch-down the H.P. cock should be closed immediately, or the F.F.P.S. disengaged to prevent the engine stalling. This is particularly important in a " stop engaged " deck landing.

70. **Actual Failure of the P.C.U. in Flight.** If the P.C.U. fails in flight :—

(*a*) Select EMERGENCY on the F.F.P.S.

(*b*) Throttle back immediately to the flight-idle gate.

(*c*) Reduce the I.A.S., adjust the throttle to maintain take-off r.p.m., and carry out the procedures described in para. 69 for the approach and landing.

71. **Engine Failure on Double-Engine Installations.** If an engine fails while flying on one engine in double-engine installations, and if there is likely to be any delay before a relight is made on the other engine, ensure that full electrical power is made available for the igniters and feathering-pump motor. Therefore switch off all non-essential electrical services. Follow the same drill as for normal relighting. The unfeathering propeller takes about four seconds longer to turn the engine up to relight r.p.m. when the second engine has been feathered and the slip-stream therefore reduced. If the correct relight procedure is followed not more than about 150 feet of height need be lost.

72. **Engine Stalling.** If the compressor stalls owing to mishandling of a turbo-prop engine, or icing, complete loss of power occurs. It may be possible to re-establish the airflow through the engine by immediately closing the throttle to the flight-idle gate. If, on carefully reopening the throttle, there is a rapid rise in j.p.t. with no increase in torque, and if the j.p.t. remains substantially above the limits in spite of throttling back, the engine must be shut down and relit.

73. **Auto-Feathering and Engine Stalling.** In single-engine turbo-prop aircraft with a reverse torque unit the propeller will not always auto-feather if the engine stalls, since the residual thrust of the engine may be high enough to prevent this. Under these conditions the drag will be very high and a fairly steep dive may be necessary to reach an I.A.S. high enough to unstall the engine.

74. **Engine Stalling on the Approach.** If the engine stalls on the approach, with the reverse torque unit inoperative, *i.e. with the F.F.P.S. disengaged*, the propeller fines-off excessively. To stop this, if time allows, the F.F.P.S. should be engaged. If time does not permit the stop being engaged, the H.P. cock must be closed to feather the propeller and recover control of the aircraft.

ENGINE ICING

Note.—The following paragraphs must be read in conjunction with the information contained in Pilot's Notes.

Centrifugal and Axial Flow Engines

75. Centrifugal compressor engines are relatively insensitive to moderate icing conditions. The combination of centrifugal force, temperature rise, and rugged construction found in these compressors is effective in dealing with all but severe engine icing.

76. Axial flow compressors are *seriously* affected by the same atmospheric conditions that cause airframe icing. Ice forms on the inlet guide vanes causing a restricted and turbulent airflow with a consequent loss in thrust and rise in j.p.t. Heavy icing can cause an excessive j.p.t. leading to turbine and engine failure.

Effect of r.p.m. on Rate of Icing

77. For a given icing intensity the closer the spacing of the inlet guide vanes, the more serious is the effect of icing. For a given engine the rate of ice accumulation is roughly proportional to the icing intensity and the mass airflow through the engine, *i.e.* to engine r.p.m. The rate of engine icing, therefore, can be reduced by decreasing the r.p.m.

Effect of T.A.S. on Rate of Icing

78. It is known that the rate of engine icing for a given icing index is virtually constant up to about 250 knots T.A.S. At higher speeds, the rate of icing increases rapidly with increasing T.A.S. This phenomenon can be explained by the fact that the rate of engine icing is directly proportional to the liquid water content of the air gathered into the air intakes; the water content of the air in the intakes is not necessarily the same as that of the free airstream. At low speeds, air is sucked into the intakes and at high speeds it is rammed in; the transition speed, at which the pressure and temperature in the intake are atmospheric, is about 250 knots T.A.S.

79. During the suction period the concentration of water content is virtually unchanged from that of the free airstream. At higher speeds, above 250 knots, most of the suspended water droplets ahead of the projected area of the intake, tend to pass into the intake while some of the air in this same projected area is deflected round the intakes. The inertia of the water droplets prevents them from being deflected and so the water content of the air in the intake is increased. *Therefore a reduction of T.A.S. to 250 knots will reduce the rate of jet engine icing.*

80. The reduced pressure caused by the compressor sucking action is at its lowest at zero speed. The pressure drop also increases with rise in r.p.m. The pressure drop is, of course, accompanied by a temperature drop. On the ground, or at very low speeds and high r.p.m., air at ambient temperature will be reduced to sub-freezing temperature as it enters the intakes. Any water content would therefore freeze onto the inlet guide vanes. The suction temperature drop which occurs is of the order of 5°C. to 10°C. This temperature drop occurs at high r.p.m. at the lowest altitudes and decreases with decreasing r.p.m. or increasing T.A.S. Under these conditions visible moisture is needed to form icing. *Therefore take-off in fog, at temperatures slightly above freezing, can result in engine icing.*

Warning Function of Airframe Icing

81. Except for the suction icing characteristic which will be rarely encountered, jet engine icing will only occur in the same conditions as airframe icing and in about the same proportion for a given icing intensity. *As a general rule, therefore, there will be little chance of engine icing in flight unless visible airframe icing is experienced.*

Indications of Rate of Icing

82. Although the rate of engine icing is roughly proportional to the rate of airframe icing for a given icing intensity, the ratio of the rates varies considerably for changing icing intensities. The rate of wing icing depends on both the water content and the size of the droplets. Engine icing depends primarily on the water content and is almost independent of the size of the droplets.

83. This is caused by the fact that very small droplets tend to follow the deflected air around the leading edge of the wing or any surface of a large radius; larger droplets because of greater inertia cannot change their position rapidly enough and so tend to impact the leading edge. The radius of the intake guide vanes is so small that the size of the droplets is immaterial. Therefore, for a given concentration of atmospheric water and for a given T.A.S. and r.p.m., the engine icing rate is constant but the wing icing rate will be lower for small droplets and higher for large droplets.

84. Because of the same phenomenon, wing icing tends to be heavier on the outer sections of the span where the leading edge is less sharply curved. The most reliable visible indication of

the rate of engine icing is obtained by watching projecting objects having the smallest radius or curvature, *e.g.* aerials, since the rate of accumulation on these items more nearly approximates that on the inlet guide vanes.

Effect of Speed on Indications of Icing

85. Although the rate of engine icing is almost constant at speeds below about 250 knots, the rate of airframe icing decreases rapidly with decreasing airspeed. This characteristic can cause a false interpretation of the rate of engine icing if the evidence of the airframe icing is taken to indicate engine conditions. For example, consider two aircraft in the same icing conditions, one flying at 150 knots and the other at 250 knots; the aircraft at 150 knots would experience mild airframe icing and that at 250 knots would experience fairly heavy airframe icing. The rate of ice accumulation at the lower speed is less than at the higher speed although the icing intensity is the same. *The engine icing rate would have been the same in both cases.* Low airspeed is highly desirable for flight in icing conditions because of the extended duration of trouble-free operation, but the pilot should not be misled by the rapid reduction of airframe icing rate achieved by a reduction in airspeed.

86. **The Fallacy of Ram Temperature Rise as an Icing Deterrent.** The idea that the adiabatic temperature rise, caused by ram effects, prevents icing, is dangerous. The common theory of ram temperature rise is a simplification of the basic theory and applies only under dry air conditions ; the presence of free water droplets nullifies the simplified law. When free moisture is present, much of the energy (heat rise) due to ram is absorbed by the evaporation of water, with the result that at moderate airspeeds there may be an actual reduction of airframe temperature ; the airspeed needs to be very high to generate sufficient ram energy to simultaneously evaporate the free moisture and raise the wing surface temperature above freezing. At speeds of about 400 knots an extremely serious form of airframe icing, leading to severe control difficulties, can be encountered.

Avoiding or Clearing Icing Regions

87. It can be stated that in stratus (layer type) clouds the actual icing region is seldom more than 3,000 feet in depth, the average depth being of the order of 1,000 feet. In cumulus (heap type) clouds, the depth of the icing layer may be considerable but the horizontal area is rarely more than three miles in diameter (one minute at 180 knots). However, the icing intensity in cumulus cloud is usually greater than in stratus type. The high performance of jet aircraft usually enables them to fly clear of icing regions before the engine or airframe is seriously impaired. The general rules are : *Change altitude (climb or descend) in stratus cloud icing, and change heading appropriately to avoid cumulus cloud icing.*

Engine Anti-Icing Equipment

88. If engine anti-icing equipment is fitted this can be switched on at any time when icing conditions are suspected or when an unaccountable rise in j.p.t. or drop in r.p.m. occurs under conditions suitable for engine icing. There are several engine anti-icing systems, all of which, with the exception of methanol injection, involve a higher fuel consumption and so a reduced range ; details are given in Pilot's Notes.

89. **Hot Air Anti-Icing System.** On some aircraft, a hot air supply from the compressor can be ducted through the hollow structure of the intake lips, the front bearing supports, and the intake guide vanes. This is essentially a method of *icing prevention* and not *de-icing*, *i.e.* ice, once formed, cannot be removed by the system. This system is intended as a means of protection only during climb and descent through an icing region and not for prolonged periods in level flight ; the system is controlled through an indicator and a switch. When anti-icing is in use a loss of thrust occurs and, at full throttle, the j.p.t. may rise above the limit.

Engine Handling with Hot Air Anti-Icing Switched On

90. Wherever the anti-icing system is in use, the throttle must be moved slowly and then left alone unless a further r.p.m. adjustment is definitely needed. After flying clear of an icing region and switching off the system, a pause of 10 seconds is recommended before moving the throttle at the usual rate. When descending through an icing region the throttle should be closed to the minimum permissible flight r.p.m. before switching on the system ; thereafter the r.p.m. should be kept constant by careful use of the throttle. If conditions require the use of the system down to airfield level, the r.p.m. must remain at or above the minimum permissible for flight until finally committed to landing. If it is essential to go round again, the throttle must be opened slowly, keeping a close watch on the j.p.t. If the

j.p.t. exceeds the limit, there is no alternative but to reduce power.

Variable Angle Swirl Vanes—Effect of Icing (No Anti-Icing Fitted)

91. When the engine has variable swirl vanes, these items become an important consideration in icing conditions. When descending through icing conditions, the r.p.m. should be set so that the swirl vanes take up their low power position, otherwise if they were to freeze at the high power setting there would be a risk of surge when flying at low power prior to landing.

92. When clear of icing conditions at a safe height and at an indicated temperature above 0°C., five minutes should elapse before the throttle is opened to increase power sufficiently to open the swirl vanes. This allows any ice to disperse while a margin of height is still available and also allows for a reduction of power if a surge develops when attempting to increase power.

93. If icing conditions persist to a low altitude, the approach and landing should be made with the r.p.m. just below that at which the swirl vanes change angle and without exceeding this angle. The throttle must be moved carefully in these conditions and the j.p.t. watched closely.

94. It should be noted that the S.F.C. is considerably impaired when flying in the conditions mentioned in para. 93 and the range and endurance therefore reduced.

95. On engines not fitted with variable swirl vanes, the recommendations of paras. 91 to 93 apply in a general sense only, and there is no necessity to restrict the r.p.m. severely during the descent unless icing is expected. In this case the normal precautions should be taken.

Turbo-Prop Engines

96. In turbo-prop installations the first indication of engine icing is usually a reduction in S.H.P. (torque) followed by a rise in j.p.t. Power should be reduced and an ice-free layer sought. If engine limitations are likely to be exceeded, or if vibration is felt, or any other symptom of compressor stalling is noticed, the throttle should be closed to the flight-idle gate. If, on gently reopening the throttle, there is a rapid rise in j.p.t. with no increase in torque, or the j.p.t. remains substantially above the limits in spite of throttling back, there is no alternative but to stop the engine and relight.

APPROACH AND LANDING

Turbo-Jet Engines

97. A powered approach is necessary on turbo-jet aircraft to ensure a quicker thrust response if it becomes necessary to adjust the glide path by use of the throttle. Pilots' Notes give a minimum r.p.m. for each engine installation for use in the approach configuration. The r.p.m. should be kept at or above this figure until the decision to land has been made and the runway can be seen. When going round again from a powered approach the throttle should be opened smoothly to full power to prevent engine surge.

98. If the decision to go round again has been made after touch-down, or just before, when the r.p.m. have fallen below the minimum approach figure, the throttle must be opened very carefully until the r.p.m. reach the minimum approach figure, otherwise the engine may surge. When opening up under these conditions the engine takes longer to accelerate to full power.

Turbo-Prop Engines

99. Engine response is poor on the approach, and early corrective action must be taken if under-shooting. There is little or no immediate impression of increase of power, and reference should be made to the torque-meter, if fitted. To ensure the maximum response when going round again, it is advisable to maintain the minimum torque-meter reading or power setting given in Pilots' Notes. The throttle should not be closed behind the flight-idle gate until the aircraft has actually touched down. If, after touch-down, the throttle is left at the flight-idle gate, deceleration is poor owing to the high residual thrust. Unless landing on long runways, there should be no undue delay in closing the throttle to the ground idle position.

100. Rapid closing of the throttle to the ground idle position causes an equally rapid fining-off of the propeller with a sudden large increase in drag. While this is useful for a rapid deceleration in the initial stages of the landing run, the discing effect of the very fine pitch is to blank the rudder and elevator, greatly decreasing their effectiveness; thus any drift at touch-down is accentuated, and a swing may easily develop requiring early and careful use of the brakes. The throttle should therefore be closed slowly and smoothly to the ground idle position. Power should not be used to check a swing as the engine response is too slow and the rapid throttle movement required will probably stall the engine. During the

landing run, once the throttle has been closed to the ground idle position, the reverse torque light may blink occasionally.

101. **Going Round Again.** If the decision to go round again is made after touch-down after the throttle has been moved to the ground idle position, the throttle must be opened *slowly* to avoid stalling the engine ; initial acceleration is very poor, and the decision to go round again should normally be made before cutting to the ground idle position.

STOPPING THE ENGINE

Turbo-Jet Engines

102. After the aircraft has landed and taxied in, the engine is usually cool enough to be stopped by closing the throttle and turning off the H.P. cock. If, however, the temperatures are above the idling values, the engine should be run at about twice the idling r.p.m. for a short period to allow it to cool. The throttle should then be closed, and after 30 seconds the H.P. cock turned off. The engine continues to turn for several minutes after combustion has ceased, and the L.P. cock should not be turned off until the engine has stopped turning, otherwise the fuel pump is run dry and air may be drawn into the system, making it necessary to reprime the system. In some aircraft the L.P. cock can be left on. Generally, if an aircraft is to remain on the ground for a long period before the next flight, the L.P. cock should be turned off after the engine has ceased turning. This prevents fuel seeping through to the flow distributor and so to the combustion chambers.

Turbo-Prop Engines

103. The engine should be run down at the correct r.p.m. to ensure even cooling, and the throttle closed to the ground idling position. The engine is stopped by closing the H.P. cock fully. The starting pitch button may be pressed to quicken the propeller feathering action and apply the propeller brake. When the propellers have stopped turning the L.P. cock should be closed.

MANAGEMENT OF THE FUEL-PUMP ISOLATING SWITCH

Note: The information below applies to all fuel systems, irrespective of whether single or dual pumps are used.

During Take-Off

104. Unless otherwise recommended in Pilots' Notes, take-off should be made with the isolating valve inoperative, *i.e.* the switch set to NORMAL. However, Pilots' Notes for some aircraft may recommend that, under certain conditions, take-off should be made with the switch set to ISOLATE, as a safeguard against engine failure. Since the B.P.C. (and A.C.U. if applicable) are inoperative when the fuel pump is isolated, and the pump output is regulated by the throttle lever alone, care must be taken when attempting to accelerate some engines from idling, otherwise over-fuelling causes a high j.p.t.

In Flight

105. Failure of a main fuel pump or its servo-system under normal conditions with the isolating switch at NORMAL is indicated by a rapid loss of r.p.m., possibly accompanied by a rapid drop in j.p.t. If this happens the throttle should be closed immediately and the isolating switch set to ISOLATE. If the engine then keeps running with a normal j.p.t. an attempt can be made to increase power, but the throttle must be moved slowly. If despite the above action the engine stops, the H.P. cock should be closed and the engine relit, *leaving the isolating switch at* ISOLATE. Having relit the engine it may not be possible to obtain maximum r.p.m. at low altitudes, as the single pump may not have the necessary output to cope with the demand at high power. When running an "isolated" engine considerable care is necessary when accelerating from idling, since coarse handling of the throttle causes over-fuelling and an excessive j.p.t.

106. **De-Isolating at Altitude.** When climbing with the switch at ISOLATE, the throttle must be closed progressively to prevent over-fuelling (the B.P.C. is inoperative). If the fuel system is serviceable, *i.e.* there has been no failure of any sort, and the switch is then moved from ISOLATE to NORMAL without moving the throttle, there is a risk of a weak-mixture flame extinction. This is because there is a rapid reduction in r.p.m. when the B.P.C. takes over and the pump output is suddenly reduced at the particular throttle opening. If the isolating switch has been inadvertently left at ISOLATE after take-off and this is discovered at altitude, the throttle must first be opened fully and then the switch returned to the NORMAL position, after which the throttle can be readjusted.

107. **Isolating at Altitude.** Moving the switch to ISOLATE at high altitude and high power can cause a rich-mixture extinction or an acceleration surge. During the climb at full

throttle or thereabouts the B.P.C. will have cut down the fuel flow automatically, and setting the switch to ISOLATE then puts the fuel pump to full stroke which, at the wide throttle opening, results in an over-rich mixture and possible flame extinction. The throttle should therefore be closed before isolating.

108. **Isolating and Relighting.** If flame extinction is due to mishandling of the engine controls, or engine icing, and thus the fuel system is not suspect, a relight can be done with the switch at the NORMAL setting. However, if flame extinction has been caused through reasons other than these, the switch should be set to ISOLATE before relighting. In this way a defective pump or servo-system is isolated.

During Landing

109. Unless a failure has occurred the switch should be at NORMAL for landing. When landing with the switch at ISOLATE the throttle must be moved slowly and evenly, otherwise surge may occur. If a landing must be made with the switch at ISOLATE the idling r.p.m. and thrust are higher. The landing run will therefore be longer unless heavier braking is used.

RELIGHTING

Turbo-Jet Engines

110. Relighting is practical with some turbo-jet engines at altitudes as high as 35,000 feet, but normally much lower altitudes are recommended to ensure a definite relight. The lower the altitude the greater the chance of a successful relight. Pilots' Notes give the recommended altitudes, airspeeds, engine windmilling r.p.m., and throttle settings required for a satisfactory relight.

111. If flame extinction occurs, as distinct from a mechanical failure, the following actions should be taken :—

(*a*) Close the H.P. cock immediately to prevent an accumulation of loose fuel in the engine which would jeopardize relighting.

(*b*) Fly at the recommended relighting I.A.S. and altitude and check, if applicable, the engine windmilling r.p.m.

(*c*) Ensure that at least one L.P. cock and booster pump is on ; that the fuel pressure warning light is out, and that there is enough fuel in the selected tanks.

(*d*) Set the isolating valve switch to the appropriate position.

(*e*) Switch on the RELIGHT and EMERGENCY booster pump if fitted.

(*f*) Set the throttle to the recommended position. Experience has shown that while some engines require the throttle to be closed, other engines relight best with the throttle partially open.

(*g*) Ensure that the master starting switch and ignition switch (if fitted) are on, but some installations will relight successfully with these switches off.

(*h*) Press the relight button and open the H.P. cock fully, keeping the relight button pressed.

(*j*) Immediately a rise in r.p.m. or j.p.t. is indicated, release the relight button and close the throttle. The engine should then accelerate to idling r.p.m. for the altitude and may then be opened up slowly to the desired figure. If the ISOLATE switch is used, the throttle must be moved carefully, watching the j.p.t.

112. With some engines, if the throttle is open only the igniter combustion chambers may light up without the flame spreading to the other combustion chambers. Therefore, if the engine has not relit within six seconds of opening the H.P. cock, the throttle, if partially open, should be closed to spread the flame to all chambers.

113. If the engine has not relit within the time given in Pilots' Notes, close the H.P. cock and wait two minutes, or the time stated in Pilots' Notes, before repeating the cycle of operations, preferably at a lower altitude and lower airspeed. In some instances a larger throttle opening has assisted a second attempt to relight.

114. If the isolating valve switch is set to ISOLATE for relighting, it should be left at ISOLATE for the remainder of the flight.

115. In some early aircraft having no relighting facilities, special instructions are given in Pilots' Notes on the actions to be taken after flame extinction.

116. When relighting, particularly in single-engine aircraft, all non-essential electrical services should be switched off to ensure the maximum output from the electrical supply.

Turbo-Prop Engines

117. **The Python 3 Engine.** Relighting turbo-prop engines is done at considerably lower heights and airspeeds than turbo-jets ; Pilots'

Notes give the details. Normally only one attempt to relight should be made. If this is unsuccessful, there is a risk of fire if a further relight is attempted. Relighting is done by windmilling only. If flame extinction occurs, the following actions should be taken to relight *as soon as possible after flame extinction* :—

(*a*) Close the H.P. cock immediately and close the throttle to the ground idle position.

(*b*) Switch off all non-essential electrical services.

(*c*) Set the F.F.P.S. switch to EMERGENCY, to ensure that the stop remains engaged whether the undercarriage is lowered or not.

(*d*) Ensure that the ignition switch, the fuel booster pump and L.P. cock are on.

(*e*) At the recommended airspeed, open the H.P. cock and press the starting pitch button. (While the engine is accelerating and before it has relit the reverse torque warning light may indicate.)

(*f*) Release the starting pitch button when the engine speed reaches 500 r.p.m. Acceleration is rapid and the throw-out speed of 2,700 r.p.m. should be reached in 3 to 5 seconds.

(*g*) Indication of a relight is slight and no indication is given by the j.p.t. A cautious throttle movement can be made above 2,700 r.p.m. ; if the r.p.m. follow the throttle movement the engine has relit. Drag will be high before the relight, but decreases when the engine has relit and the reverse torque warning indicator goes out. White vapour from the jet pipe may indicate failure to relight.

(*h*) If the engine has not relit when 3,000 r.p.m. are reached, the H.P. cock must be closed and the propeller feathered.

118. **The Double-Mamba 100 Engine.** After flame extinction, close the H.P. cock immediately to FEATHER and BRAKE, switch off non-essential electrical services, and then carry out the following actions :—

(*a*) Close the throttle *fully* to the ground idle gate.

(*b*) Set the F.F.P.S. switch and the auto-j.p.t. control switch to NORMAL.

(*c*) Switch on the starting fuel-pump master switch.

(*d*) Open the H.P. cock and press the relight button. Release it at 1,500 to 2,000 r.p.m. Check the ignition warning light, j.p.t., and oil pressure.

119. The r.p.m. build up rapidly and the throttle should be opened smoothly to the flight-idle gate at about 8,000 r.p.m. Reverse torque action then automatically prevents the r.p.m. from increasing too quickly. When the engine is running smoothly, open the throttle to the desired setting.

120. If the engine does not relight close the H.P. cock to FEATHER and BRAKE before repeating the relighting cycle.

121. Do not attempt to relight when the undercarriage is down, *i.e.* with the F.F.P.S. disengaged, as propeller drag may cause a considerable loss in height. In an emergency, if a relight becomes necessary with the undercarriage down, the F.F.P.S. switch must be set to ENGAGE before relighting.

Flame Extinction on Gas-Turbine Engines

122. Flame extinction may be caused by overfuelling, underfuelling, interruption of the fuel flow, or insufficient idling speed.

123. **Overfuelling.** Overfuelling may be caused by isolating a fuel pump without first closing the throttle, or by a too rapid throttle acceleration when the fuel pump is isolated.

124. **Underfuelling.** Underfuelling can be caused by closing the throttle too rapidly when one pump is isolated, or by failing to open the throttle before de-isolating the pump. Even when a minimum-burner-pressure valve is fitted this can still occur at altitude.

125. **Interruption of the Fuel Flow.** Fuel flow interruption for even a brief instant causes flame extinction. Inverted flying for longer than the permissible limits, or inadvertent closing of the fuel supply, also results in flame extinction.

126. **Insufficient Idling Speed.** Possibly owing to a maladjusted minimum-burner-pressure valve (if fitted), the r.p.m. fall below the minimum self-sustaining speed when the throttle is closed. When closing the throttle fully in flight, check the idling r.p.m., which should increase with altitude.