PART 1 : SECTION 2

CHAPTER 7

ENGINE HANDLING

ENGINE LIMITATIONS

Introduction

1. Pilots' Notes for each type of aircraft specify certain engine limitations. These limitations are based on calculations and type tests on the bench. They may subsequently be modified in the light of service experience and operational requirements. While normally the same for any one type of engine, they may vary for the same engine when fitted in different types of aircraft. The limitations are designed to secure an adequate margin of safety against immediate breakdown and to give the engine a reasonable life. Proper handling throughout the life of an engine will improve reliability towards the end of the periods between overhauls, and will also improve the chance of the engine standing up to operational overloads.

2. With all engines, optimum reliability and long trouble-free life are assured by restricting the use of the higher powers as much as possible. During take-off the aim should be to use full take-off power for the shortest practicable time, the power being reduced as soon as this can safely be done. On lightly loaded aircraft it may not be necessary to use the full permitted boost if experience with the aircraft shows that for particular conditions of weight, weather, and available take-off run, take-off can safely be made at lower power without having to use this reduced power for a disproportionately long period. Similarly, the climb should be made at less than the full intermediate power permitted, even within the weak mixture range, provided that overheating does not result and an acceptable rate of climb can be maintained.

Engine Limitations

3. If the specified engine limitations are exceeded or extended beyond the time permitted, a report must be made after landing.

4. The stresses and wear are increased at high r.p.m. owing to inertia loading, and at high boost owing to high gas pressures causing high piston and bearing loads. Consequently maximum r.p.m. and boost limitations are usually imposed which apply at the four basic power conditions shown in para. 7.

5. High cylinder temperatures lead to a breakdown in cylinder wall lubrication, excessive gas temperatures, detonation at high boosts, and distortion. High oil temperatures cause failure of cylinder and bearing lubrication. Accordingly, maximum cylinder (or coolant) and oil temperature limitations are also imposed for the four main power conditions.

6. Shortage of oil, or a defect in the lubrication system, may result in inadequate lubrication and bearing failure. A minimum oil pressure limitation is therefore included.

7. The following table of engine limitations for a liquid-cooled engine is typical of those quoted in Pilots' Notes. It shows the principal limitations associated with each of the four main power conditions.

	Gear	*r.p.m.*	*Boost lb./sq. in.*	*Temp.* °C. *C'lant*	*Oil*
Max. Take-Off 5 mins. limit	Low	2,750	+12	—	—
Maximum Intermediate 1 hr. limit	Low High	2,600	+ 9	125	90
Maximum Continuous	Low High	2,400 2,600	+ 7	105	90
Operational Necessity 5 mins. limit	Low High	2,750	+18	135	105

Oil Pressure :
Minimum ... ... 45 lb./sq. in.

Minimum Temp. for Take-Off :
Oil ... ... + 15°C.
Coolant ... ... + 40°C.

Considerations for Imposing Engine Limitations

8. Minimum oil and cylinder head or coolant temperatures are specified to ensure the proper circulation of the oil and to prevent damage or failure owing to rapid and uneven heating at high powers.

9. A maximum cylinder head temperature for take-off is given for air-cooled engines to ensure that the high power used at take-off will not cause the temperature to exceed the maximum permissible. This limitation is *not* necessary on liquid-cooled engines since the coolant temperature does not rise so rapidly.

(*A.L.* 2, *Jan.* '55)

10. The r.p.m. to be used in conjunction with take-off or operational necessity power are quoted, since the use of lower r.p.m. will cause excessive bearing loads and detonation at the high boosts. If the r.p.m. are lower than the permitted figure, the volumetric efficiency of the engine is increased and higher cylinder pressures and an increased weight of charge per stroke are obtained at the same boost, thus overloading the engine. When no minimum r.p.m. figure is quoted for these conditions, a good practical rule is to avoid the use of take-off boost at r.p.m. more than 150 below the maximum r.p.m. permitted for take-off. When a boost greater than the take-off limit is allowed for operational necessity it should never be used at a lower r.p.m. than that used for take-off.

11. A maximum cylinder head temperature at which the engine can be stopped after flight is imposed to prevent overheating of the ignition harness and distortion of the cylinders caused by the rapid and uneven cooling on stopping the engine. All engines should be run at or a little above the warming-up r.p.m. to obtain even cooling and to leave an adequate film of oil on the cylinder walls.

12. A diving r.p.m. limitation is imposed on certain engines having propellers with a fixed or limited pitch range on which the normal maximum r.p.m. may be exceeded in a dive. The diving limit is usually allowed for a period of only 20 seconds with the throttle more than one-third open. Pilots' Notes for such aircraft quote this limitation.

13. On all piston-engine aircraft overspeeding may occur during a dive and in other conditions of flight, particularly if the constant speed unit operates sluggishly or is defective. Overspeeding of this nature should be of a momentary nature, but if it persists the airspeed must be reduced as quickly as possible, the throttle closed and, if the propeller still will not constant-speed, an attempt must be made to feather it. If overspeeding exceeds 5 per cent. of the maximum permitted r.p.m., or persists for more than 20 seconds, the engine may be damaged. This is the significance of the overspeed limitations given in certain engine publications, although such limitations do not appear in Pilots' Notes for the type.

Mixture Setting

14. **Manual Mixture Control.** In engines with manually operated mixture controls, the mixture must be set to rich before the boost is raised to a figure greater than the maximum weak mixture boost specified.

15. **Automatic Mixture Control.** There are two main methods of automatic mixture regulation :—

(*a*) The throttle lever is set to give not more than the maximum weak mixture boost, thus ensuring that the mixture is correctly set.

(*b*) The throttle lever is set at or behind the economical cruising position marked on the quadrant.

With engines using type (*a*) some care is necessary, particularly when flying at or near full throttle height, to ensure that rich mixture is not being used inadvertently. To ensure that weak mixture is in use under these conditions, the throttle should be opened fully then slowly closed until the boost starts to fall ; this position will then give the required weak mixture setting. If at any time the fuel consumption appears to be high, a check should be made to see that weak mixture is in fact being used.

Interconnected Throttle and r.p.m. Controls

16. Used almost entirely on piston-engine fighters, this system ensures that whenever the throttle is moved to increase or decrease the boost the r.p.m. are automatically varied to suit the boost. This interconnection is obtainable only when the propeller control is set to the "AUTO" position.

Reduction of Permitted Take-Off Boost

17. On certain engines the maximum boost permitted for take-off may be unobtainable owing to the low ram effect at take-off speeds, the use of hot air or intake filters, the altitude of the airfield, or high atmospheric temperatures.

Effects of Failure of the Lubrication System

18. Serious damage may occur quickly through overheating or failure of the lubricating system, and the limitations should be strictly observed. Frequent checks should be made of the oil temperature and pressure, and the cooling controls and/or power should be adjusted when necessary.

19. **Variations in Oil Pressure.** On many in-line engines the oil pressure under normal conditions tends to vary through a considerable range, increasing with r.p.m. but dropping with a rise in temperature. Older engines tend to run at lower pressures as the bearing clearances

increase with wear. The minimum oil pressure limitation is, however, the lowest at which satisfactory lubrication is obtained. When Pilots' Notes specify normal oil pressures, these are for guidance only and are not necessarily representative of all engines of the same type.

20. **Warning of Impending Failure.** If an engine, which has been running normally with the oil temperatures and pressures within the limitations, is found to develop, fairly suddenly, an abnormal drop in pressure or rise in temperature, this symptom may be the first indication that trouble is developing. Even if the temperature and pressure remain within the limits, the sudden change in conditions is suspect and, depending on the circumstances, the propeller should be feathered or, with single-engine aircraft, a landing made as soon as possible.

21. When checking the engine before take-off, if the oil pressure is apparently lower than that normally experienced under comparable conditions a defect should be suspected.

Boost and r.p.m. Relationship

22. Although under any given power conditions neither the boost nor the r.p.m. limitations should be exceeded, it is permissible to operate for short periods at combinations of r.p.m. up to the take-off limitation and lower boost, *e.g.* when taking-off at light A.U.W.

23. When maximum weak mixture boost is in use, the r.p.m. can be reduced to the minimum obtainable. At maximum continuous rich mixture boost, low r.p.m. can also be used on most engines. If, however, the required cruising speed can be maintained by the use of a weak mixture boost this should be done unless the rich mixture is needed to prevent excessive engine temperatures.

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Taxying

24. Care must be taken to avoid overheating the engine while taxying; the throttle should be used as little as possible and set to a position which gives a safe speed. The gills or radiators should be fully open and the temperatures watched.

25. The r.p.m. control levers should be in the take-off position to obtain the best cooling airflow over the engine and provide the most tractive effort. The engine r.p.m. should be at or above the warming-up figure; the use of lower r.p.m. should be avoided as far as possible. The time spent on the ground should be kept to a minimum as many installations overheat.

Take-Off

26. If the engine is not run up immediately before take-off, air-cooled engines should be cleared by opening up to the static boost reading, or at least to the highest boost that can be held on the brakes. This is to clear the plugs and/or remove excess fuel from the supercharger casing. On liquid-cooled engines this will only be necessary after having idled for a considerable time.

Use of Intake Filters and Heat Controls

27. These should be set as recommended in Pilots' Notes. Filters should always be used when operating in dust-laden zones; on some aircraft they are automatically brought into action when the undercarriage is down.

28. When starting the take-off the throttle should be opened steadily up to the required power, the aim being to obtain full power in the shortest time consistent with the controllability of the aircraft and the desirability of avoiding slam accelerations.

Climbing

29. On most engines the r.p.m. and boost are automatically maintained at the values set by the pilot until the full throttle height for that power is reached. If the climb is continued above this height the boost then falls progressively.

30. When a two-speed supercharger is fitted, changing to high gear permits a second full-throttle height to be reached. With each gear the boost control unit automatically adjusts the throttle butterfly as height increases, until it is opened fully at the respective full-throttle height, after which the boost falls.

31. High gear should be engaged at the height recommended in Pilots' Notes or, at the height when the climbing boost in low gear has fallen by two lbs. Every boost setting has its own full-

throttle height for a given r.p.m.; the lower the boost the greater the full-throttle height (see Fig. 1). The height above which high gear must be used for maximum power varies with the boost, r.p.m., and T.A.S.

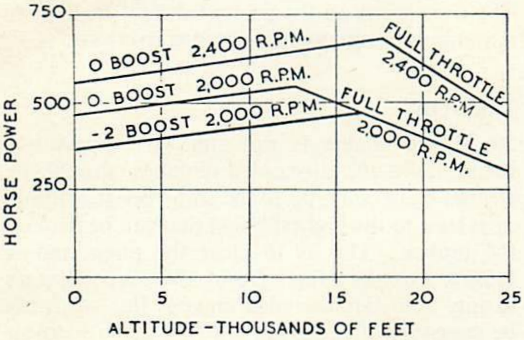

Fig. 1.
Variation of Full-Throttle Height with Power.

32. On some engines the butterfly cannot open fully unless the throttle lever is advanced up to or beyond a certain position on the quadrant. Therefore when climbing it is necessary to open the throttle when the boost begins to fall. The variation of boost with r.p.m. is caused by the fact that increasing r.p.m. also increases the supercharger's speed and enables it to maintain a required boost up to a greater altitude. The variation of boost with airspeed arises from ram effect which helps the supercharger at high T.A.S. and consequently raises the full-throttle height considerably. Representative figures are shown in the table below.

T.A.S.	170	260	345 knots
Add to full-throttle height	1,000	2,250	4,000 feet

General Handling

33. The throttle lever should always be moved slowly and evenly to avoid undesirable strain on the engine and overspeeding of the propeller, which otherwise may not have time to readjust its pitch. The r.p.m. control lever should also be moved slowly as otherwise the r.p.m. are likely to overshoot the desired figure.

34. **Changing Supercharger Gear.** The supercharger gear change must be effected smartly and firmly if the change is made by a lever. In most aircraft the manual change is made by means of a switch.

35. **Increasing and Decreasing Power.** At high boost, if an increase in power is required the r.p.m. should first be raised, and conversely if a reduction in power is required the boost should first be reduced. However, combinations of excessively low boost and high r.p.m. should be avoided, as the boost pressure acts as a cushion in the cylinder head thus preventing excessive inertia stresses.

36. **Aerobatics.** Aerobatics should be carried out with a high r.p.m. setting, in order that high power can be obtained by advancing the throttle lever. This precaution and those in para. 35 prevent danger of detonation, with consequent damage to the engine.

37. **Clearing the Engine in Flight.** When cruising at low power, it is advisable to clear liquid-cooled and some air-cooled engines at regular intervals by opening up to not less than intermediate power. Clearing in this manner should be carried out once an hour or more frequently, depending on the circumstances or as recommended in Pilots' Notes for the type. This procedure is not normally necessary with the later air-cooled engines, or with liquid-cooled engines fitted with automatic charge temperature control. If a charge temperature gauge is fitted, clearing should only be necessary if the temperature has been allowed to fall below the minimum stated in Pilots' Notes for the type. (See also para. 39.)

38. Before entering the circuit at the conclusion of a flight, engines should be cleared as recommended in para. 37. This will minimize plug fouling and ensure that full power will be available if required, and is especially necessary if the engines have been running for a long time at very low power in cold weather.

39. **Charge Temperature Gauges.** With engines fitted with two-stage superchargers, on which the charge temperature is not controlled automatically, the charge temperature may fall excessively at low-power settings. If a charge temperature gauge is fitted, r.p.m. should be increased as necessary to prevent the charge temperature falling below the minimum. When neither automatic charge temperature control nor charge temperature gauges are fitted, the use of low r.p.m. should be avoided under conditions of extreme cold unless maximum range is of paramount importance. If the use of low r.p.m. is unavoidable the engine should be cleared as directed in para. 37.

40. **Ignition Checks in Flight.** If the pilot has reason to suspect the ignition system, a landing as soon as practicable is generally recommended. An ignition check in flight will not give a true indication of the full extent of the r.p.m. drop which will be masked by the constant speed unit. Furthermore, if one magneto has failed completely, harm may result from wetting otherwise serviceable sparking plugs. There is also a risk of blow-back and damage to the engine when the ignition is switched on again.

Effects of Low and Negative *g* on the Carburettor

41. When an aircraft is suddenly put into a dive, or is subjected to certain aerobatics or inverted flying, fuel moves to the top of the tanks. In float-type carburettors, flooding first takes place and a rich cut is experienced, followed by a weak cut if negative *g* is sustained. The engine will cut less readily and recover more quickly with the throttle well open, but the pilot must close the throttle before power begins to return to avoid serious overspeeding of the engine, as otherwise the propeller will be unable to readjust its pitch quickly enough to cope with a rapid return of high power.

42. The effect on the oil system is similar to the effect on the fuel system, and the engine will stand only momentary running at less than the minimum oil pressure given in Pilots' Notes.

43. Injectors and injection carburettors are not affected by low and negative *g*, while the anti-*g* float-type carburettor is immune except at low power, when its behaviour is similar to that of the standard float-type fitted with a restrictor. The effect of a restrictor is to reduce the recovery period from about 10 to 5 seconds. Sustained negative *g* will nevertheless lead to a weak cut in spite of the use of a restrictor.

Engine Temperatures

44. The importance of watching cylinder head or coolant and oil temperatures, and keeping them within the limitations, cannot be too strongly emphasized. The cooling of air-cooled cylinders is controlled by the setting of gills which in general should be :—

(*a*) Fully open for all ground running, provided that the cylinder head temperatures have reached + 100°C.

(*b*) Closed or part open for take-off.

(*c*) Adjusted in flight as required.

If the gills are closed, drag is minimized and during take-off safety speed is reached earlier. On most types the cowling gills are controlled by switches marked "OPEN", "OFF", and "CLOSE". To operate the gill motor, the switch is depressed and the gills set as required ; when the desired setting is reached, as shown by the gill position indicator, the switch should be turned off.

45. The cooling of liquid-cooled engines is in most cases regulated automatically, but the pilot may have control over the flow of air through the radiator. Radiator shutters should be open only as much as is necessary for adequate cooling, thus reducing the drag.

46. The temperatures of all types of engines can be reduced by climbing the aircraft at some 10 to 15 knots faster than the recommended climbing I.A.S. without seriously affecting the rate of climb. Climbing in weak mixture may lead to high temperatures.

47. On liquid-cooled engines the oil cooler is generally incorporated in the coolant radiator and control is automatic. On air-cooled engines the cooler is separate and control is either automatic or manual. Excessively high temperature and/or low pressure indicates that the engine has been overworked, or that the oil cooler is not working properly, or that some defect has developed. Another reason, described below, is coring.

48. **Coring.** Coring is a phenomenon which occurs in some oil coolers at low atmospheric temperatures when the oil congeals and restricts the flow through the cooler. Should this occur, the action is either to close the shutters or increase r.p.m. as soon as a sudden rise in oil temperature is noticed which is not accompanied by a corresponding rise in coolant or cylinder head temperatures. If, however, coring is well advanced and the oil temperature still remains high, the undercarriage and/or flaps should be lowered to reduce speed, and hence the airflow through the cooler, without reducing power. A descent to a warmer level is then advisable.

49. Generally the engine should not be allowed to get cold or it may not readily respond when required. During descent the engine may be kept warm by diving moderately with the throttle well open, rather than by gliding with the throttle closed. In a long glide the gills of air-cooled engines should be closed and the throttle opened at intervals.

Stopping the Engine

50. The correct method of running down and stopping an engine is just as important as the correct starting and running up procedures. Use of the correct procedure ensures that an engine is cooled down in the best way and that it is left in the most serviceable condition for future starting.

51. **Effect of Excessive Temperature.** If a hot engine is shut down too rapidly, uneven cooling will result. This may cause damage to the cylinder block and distortion of the cylinders themselves. To ensure even and gentle cooling, the cowling gills or radiator shutters should be opened immediately after landing, and on reaching dispersal the aircraft should, if possible, be parked into the wind.

52. **Exercising of Supercharger Gear Change Mechanism.** On engines using an oil-operated clutch to operate the supercharger gear change, it is necessary to exercise the clutches by changing gear once every two hours. This ensures that the gear change does not become jammed through oil sludge collecting on the clutch plates. If this exercising is not done in the air before landing, it should be done at this stage of the run-down procedure.

53. **Suspect Engines.** If for any reason the serviceability of the engine is in doubt, such of the run-up checks as may be required should be carried out. These checks should not normally be necessary, but if a fault is suspected it is better discovered when stopping an engine rather than subsequently when starting it before flight.

54. **Duration of Run-Down.** The engine should be cooled by idling at the r.p.m. recommended in Pilots' Notes, usually between 800 and 1,200. The idling period varies with the type of engine, but is normally one or two minutes, or, in the case of radial engines, until the cylinder head temperatures fall to those recommended before shutting down, whichever is the longer. Idling at the recommended r.p.m. allows the scavenge pump to remove the surplus oil from the crankcase, thus reducing the danger of a hydraulic lock when starting up. Very low idling r.p.m. should be avoided as they may cause fouling of the plugs. The magnetos should be tested for a dead cut during this idling period.

55. **Stopping the Engine.** To stop an engine, close the throttle and operate the slow running cut-out or the fuel cut-off. After the engine has stopped, switch off the ignition and turn off the fuel. Cowling gills should be left open. Any additional instructions for stopping the engine are given in Pilots' Notes for the type.