

CHAPTER 3

SUPERCHARGERS AND FLOAT TYPE CARBURETTORS

Objectives

1. This Chapter has been written with the aim of helping you to satisfy objectives in the relevant Skills and Knowledge Specifications (SAKS) for the trade in this subject area. When you have studied this Chapter you will be able to:
 - a. Explain the function and operation of a float type carburettor and how the correct manifold air pressure is maintained under all operating conditions.
 - b. State the limitations of a float type carburettor.
 - c. Describe the effects of fuel spillage on yourself and on engine components.
 - d. State the safety precautions to be observed when removing and fitting carburettors.
 - e. State the method of cleaning jets.

Introduction

2. Carburation is the process of metering the correct amount of fuel for mixing and vapourizing with the air induced into the engine, to form a suitable combustible mixture. The proportions of fuel to air in a chemically correct or normal mixture is approximately 1 to 15 by weight. This mixture is *theoretically* the most efficient for all engine running conditions, but *in practice* it is sometimes necessary or advantageous to use either a rich mixture (one with a higher proportion of fuel) or a weak mixture (one with a higher proportion of air). To do this in its simplest form, so that the necessary amount of fuel forms the most suitable mixture for any engine running conditions, either a float type carburettor or some form of fuel injection carburettor is used. Variations in the mixture strength are required for:
 - a. Engine starting.
 - b. Slow running.
 - c. Acceleration.
 - d. Cruising at low altitude.
 - e. Cruising at high altitude.
 - f. Full throttle power for take-off or in an emergency.
3. Before discussing the principles of a simple type carburettor and its components, followed by a description of the fuel injection carburettor (in Chapter 4) it will be opportune at this point to remind you of the supercharger.

Supercharger

4. The principle of superchargers was discussed in Chapter 2, para. 26. There, we saw that the use of a supercharger:
 - Counteracted the effect of a fall-off in power with increasing altitude.
 - Supplied a heavier-than-normal charge at ground level, thereby increasing power without additional weight.

5. By bringing the supercharger into action as the altitude is increased, a more or less constant power, equal to ground level power, is obtained at all heights that are within the scope of the supercharger. The height up to which the normal maximum induction manifold pressure can just be maintained is known as 'rated altitude'.

6. In a supercharged engine, the induction system pressure, between the outlet of the supercharger and the cylinder, is called manifold air pressure; it is measured in inches of mercury (inches Hg). Gauges are calibrated in inches Hg—standard atmospheric pressure, equal to 29.92 inches Hg. A difference in reading of 2 inches Hg is approximately equal to a difference of 1 psi. (Note: 14.7 psi (1.000 bars) = 29.92 in Hg.) An example of a supercharged induction system is illustrated at Fig 1.3.1.

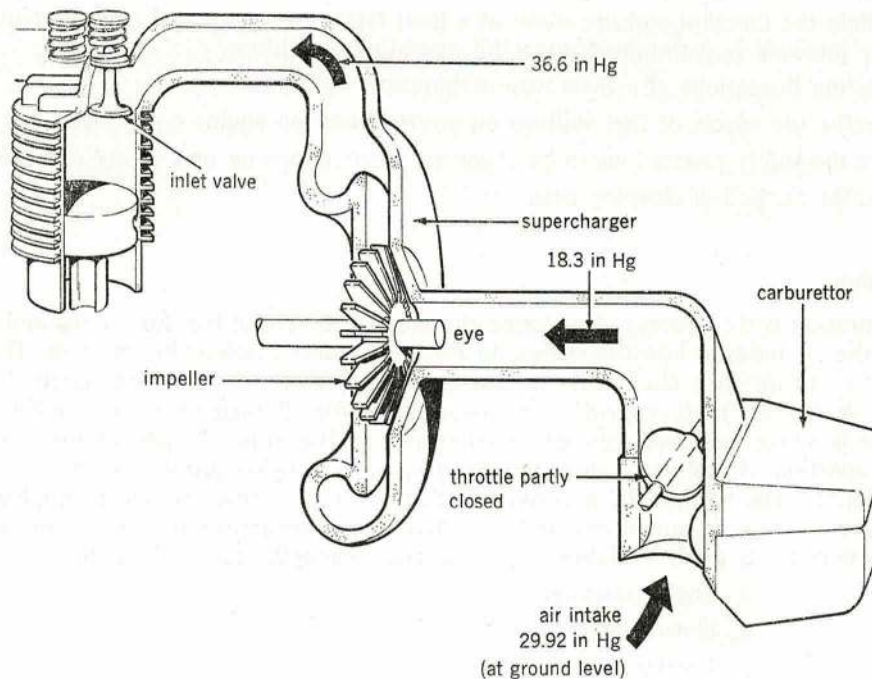


Fig 1.3.1 A supercharged induction system

Manifold Pressure Control

7. The power output of an engine will increase as the manifold pressure is raised, but eventually the corresponding increase in cylinder head temperature and the onset of detonation begins to overload the engine so that the manifold pressure must be curtailed automatically. The manifold pressures specified as being safe for various flight conditions are detailed in the Operating Limitations for the engine in Volume 1 of the particular engine Air Publication.

8. Since the manifold pressure obtained depends on the inlet pressure, if the inlet pressure is controlled, the manifold pressure will also be controlled. The inlet pressure to the impeller eye can be controlled quite easily by a throttle valve fitted between the air intake and the impeller eye. The position of the throttle valve to obtain a selected manifold pressure could be

controlled by a lever in the cockpit but, as stated, this arrangement must be automatic and so an automatic manifold pressure control is fitted to open or close the throttle valve, and the pilot's 'throttle lever' is used to select the pressure at which the manifold pressure is governed.

9. The type of manifold pressure control unit most commonly used is known as a variable datum pressure control. The pilot's control lever is used to set or select the required amount of manifold pressure. The automatic control regulates the throttle valve opening to keep the manifold pressure at the selected value for as long as the supercharger can meet the demand.

10. **Description.** The operation of a manifold pressure control depends on the ability of a sealed capsule to vary its length with variations of internal pressure. The capsule in the control, illustrated at Fig 1.3.2, is positioned in a casing and is subjected externally to the actual manifold pressure. The capsule itself is sealed at 14.7 psi (29.92 in Hg). Any rise in manifold pressure causes the capsule to contract and any drop in manifold pressure causes the capsule to expand.

11. One end of the capsule is secured to a piston valve which controls the opening and closing of ports leading to each side of a servo piston. Pressure oil (or pressure air) is fed to the centre groove of three grooves that are machined around the piston valve. The two outer grooves are connected to the oil (or air) scavenge or drain system. Attached to the other end of the capsule is a spring loaded cap which bears against a cam or cam-operated lever. Movement of the cam, which has a progressively increasing lift and is directly controlled by the throttle lever, repositions the cam assembly in the casing.

12. **Operation.** When the throttle is opened to select a particular manifold pressure, the cam lowers the capsule and valve assembly in the casing. The valve then uncovers the ports to the servo piston, and causes pressure oil (or air) to pass below the piston and connects the port above the piston to the scavenge or drain. The resulting upward movement of the servo piston opens the throttle valve and the manifold pressure rises. With a rise in manifold pressure, the capsule will gradually contract and lift the piston valve until, at the selected manifold pressure, the servo ports are blanked off, leaving the servo piston holding the throttle valve at the correct setting.

13. With the aircraft in a steady climb, the fall in the air intake pressure causes the manifold pressure to drop. This is corrected by the resulting expansion of the capsule which opens the servo ports and directs the pressure to lift the servo piston and give the wider opening of the throttle valve required to maintain the selected manifold pressure. This sequence continues during the climb, until the throttle valve is fully open (full throttle height), when any further increase in altitude will cause the manifold pressure to fall in proportion to the drop in pressure at the air intake.

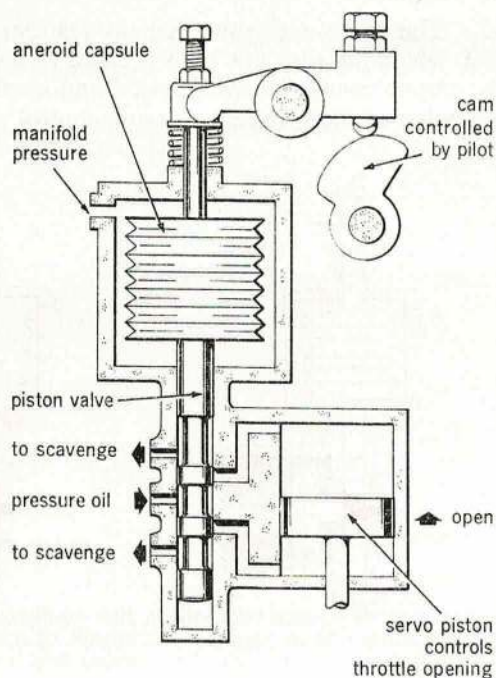


Fig 1.3.2 Automatic manifold pressure control unit

14. When an aircraft reduces height, the rise in the air intake pressure causes the manifold pressure to rise. This is corrected by the contraction of the capsule, which directs pressure above the piston and so reduces the throttle valve opening to maintain the selected manifold air pressure.

15. This cycle is effective for any manifold pressure that can be selected by the throttle lever and, where the cam has been profiled to conform to the operational limitations of the engine, the engine cannot be overboosted and continued throttle lever adjustment is eliminated. The operation of the manifold pressure control unit is illustrated at Fig 1.3.3.

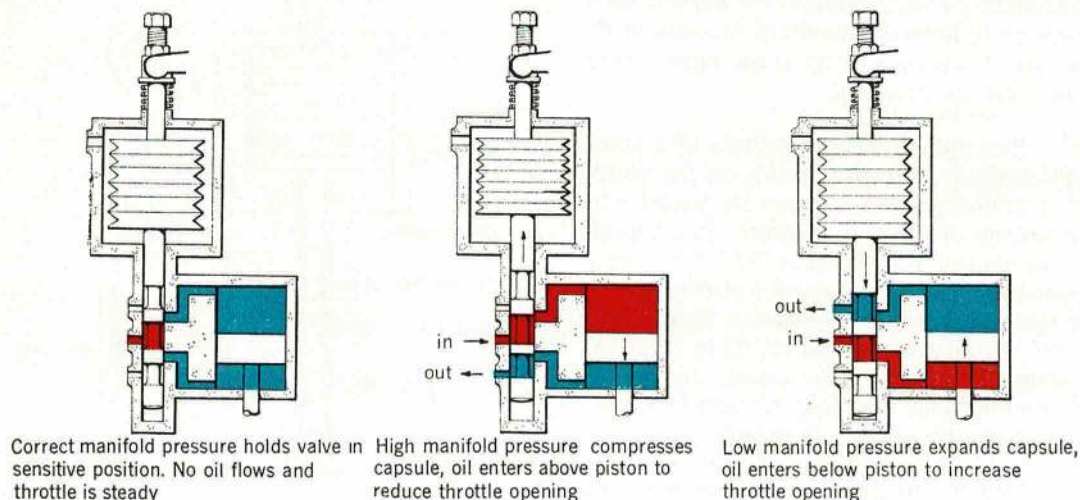


Fig 1.3.3 Operation of manifold pressure control unit

16. **Manifold pressure reversal.** Manifold pressure reversal, *ie* when the pressure rises on closing the throttle lever, occurs during the idling range of those supercharged engines that have a large angle of valve overlap. The pressure in the induction manifold over this range may be as low as 12 in Hg below normal atmospheric pressure, with the result that, as the throttle is closed and the rev/min approaches idling speed, air from the atmosphere can enter the induction system. The entry is made through the exhaust port, across the cylinder and through the inlet port, to the induction manifold during the period of valve overlap. This additional air upsets the fuel/air mixture ratio and so produces rough and unstable running. It also counters the operation of the manifold pressure control by producing a higher boost than that selected, so that the control tends to close the throttle valve and stop the engine accelerating. To avoid the effects of this reversal it is usual to inter-connect the throttle lever to the throttle valve and to design the profile of the cam of the manifold air pressure control unit, so that the throttle valve is operated solely by the throttle lever during the initial stages of throttle opening.

17. With all engines some safety device is incorporated so that, should the control unit fail, the unit is isolated and the pilot has control of the engine power through the throttle lever. It is usual to provide a constant leakage past the servo piston by allowing ample clearance in the cylinder. This reduces 'hunting' of the piston and leads to a more stable manifold pressure.

18. Now that we have dealt with the problem of maintaining the correct amount of air pressure in the manifold we shall deal with the supply of fuel in a simple float type carburettor. We shall then discuss the disadvantages of this system and show why an injection type carburettor is preferred.

The Simple Float-type Carburettor

19. In its simplest form, the carburettor may consist of a tube or jet mounted in a larger tube in which is arranged a throttle valve and a choke tube. In addition, the jet is connected to a float chamber, vented to atmosphere. The float chamber houses a float operating a needle valve. A predetermined and constant level of fuel is maintained in the float chamber by means of the float and needle mechanism. A simple type carburettor is illustrated at Fig 1.3.4.

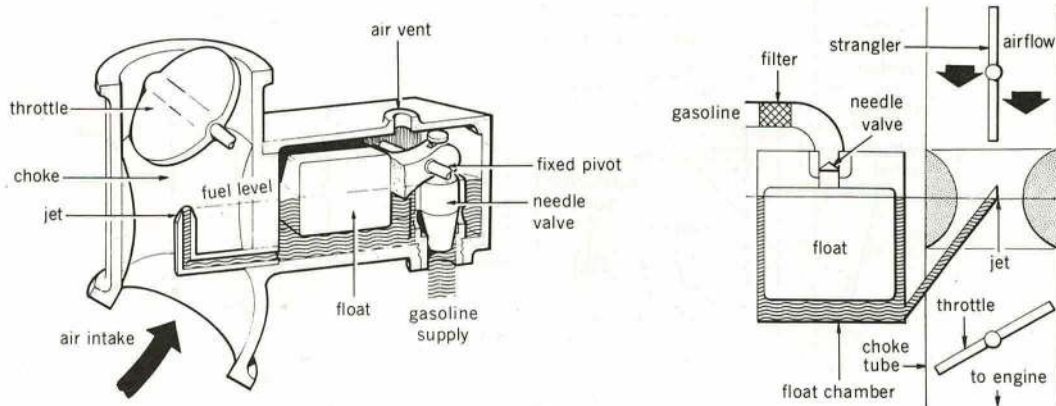


Fig 1.3.4 A simple carburettor

20. **Operation.** A simple type carburettor works on the 'U tube principle' which is illustrated in Fig 1.3.5. Air drawn into the engine cylinder, governed by the degree of throttle opening, enters the carburettor through the air intake. At the restriction caused by the choke tube, the velocity of the air within the choke tube increases, and the pressure decreases; thus, in the region of the jet we get pressure below that of atmosphere. As the fuel in the float chamber is subject to atmospheric pressure (a higher pressure than around the jet), fuel issues from the jet and mixes with the air stream flowing to the engine cylinder. The fall in the level of the fuel in the float chamber lowers the float which lifts the needle valve off its seating (Fig 1.3.4), permitting more fuel to flow into the float chamber to replace that issuing from the jet.

21. Any increase in air flow through the choke tube will increase the pressure *difference* acting across the jet and consequently increase the fuel flow. The fuel flow, however, does not vary proportionately with greater air flow, and the mixture obtained

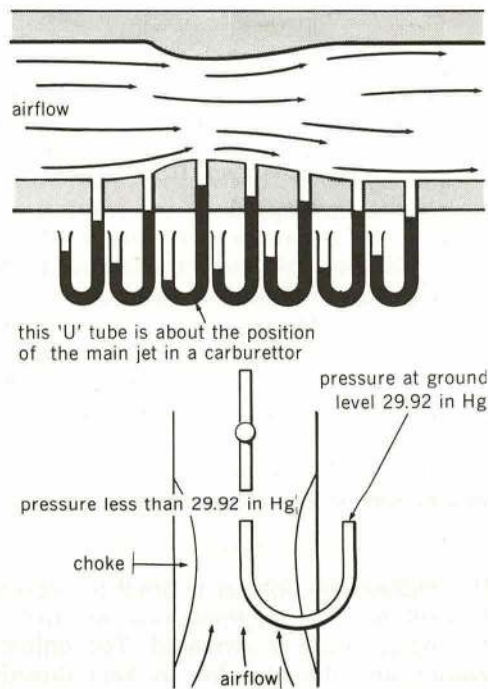


Fig 1.3.5 The 'U' tube principle

from the simple carburettor becomes progressively richer as the engine speed is increased. Various modifications must, therefore, be made to the simple carburettor to meet the requirements of the aero-engine carburettor. A modified carburettor is illustrated at Fig 1.3.6.

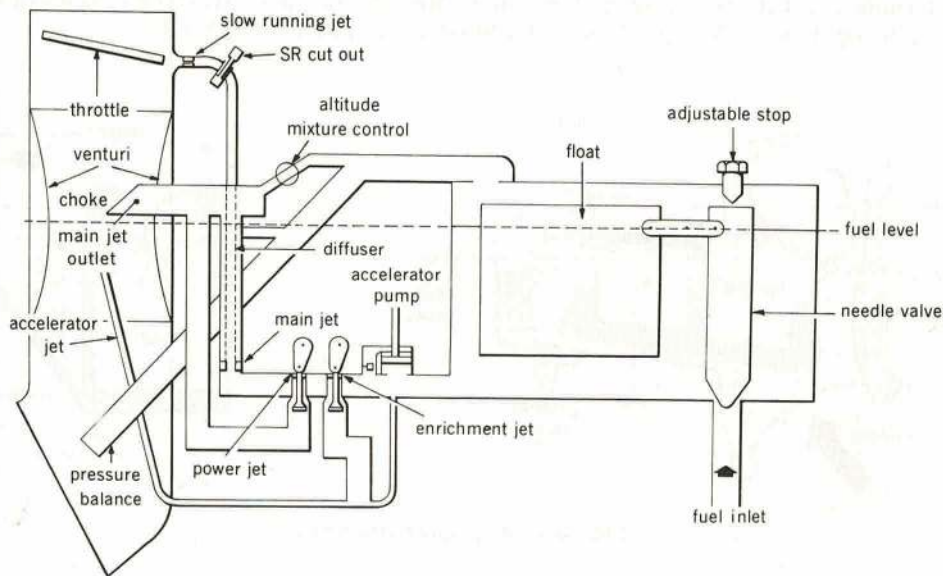


Fig 1.3.6 A modified carburettor

22. **Pressure balance air system.** To prevent upsetting the rate of discharge of fuel from the jet, the atmospheric pressure in the air intake and in the float chamber must be equal. Admitting atmospheric pressure into the float chamber through a drilling in the float chamber cover is not a satisfactory method of ensuring equalized pressures on an aero-engine carburettor because, due to manoeuvre and speed of an aircraft, the changes of pressure localized around the air intake would not be readily transmitted to the float chamber. Equalized pressure conditions, however, are obtained by admitting atmospheric pressure to the float chamber through a tube or duct opening into the air intake. This pressure balance duct also supplies air to the diffuser and is used in some carburettors to provide altitude mixture control. The pressure balance duct is illustrated at Fig 1.3.7.

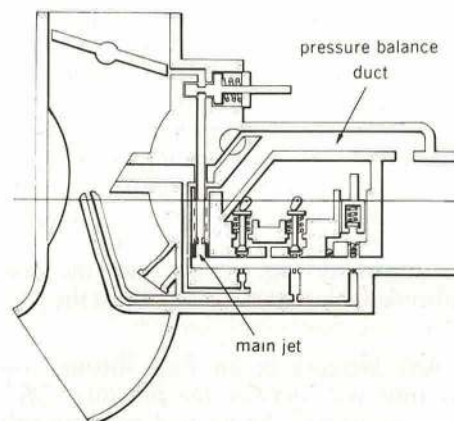


Fig 1.3.7 A pressure balance air system and diffuser

23. **Diffuser.** A diffuser is fitted to prevent the main jet from supplying excessive fuel as the engine speed is increased. The diffuser ensures that the fuel flow is kept directly proportional to the volume of air flowing through the choke. The diffuser is basically

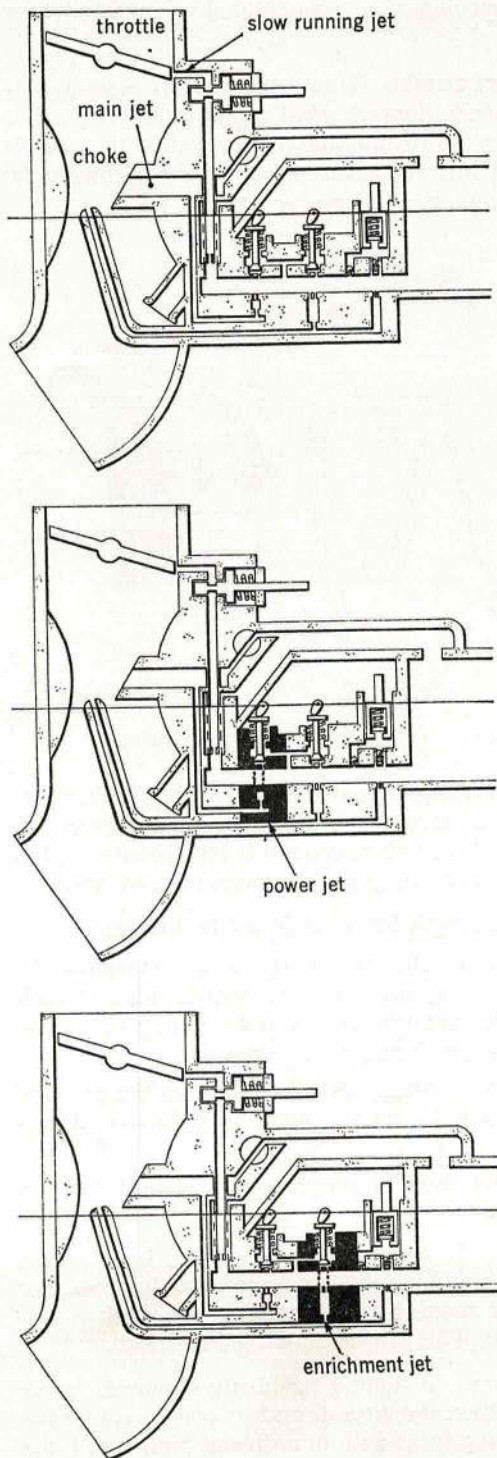


Fig 1.3.8 Slow running, power and enrichment jets

a tube drilled with a number of holes, and is positioned in the body of the carburettor above the main jet. The annular space between the diffuser and its housing is in communication with the pressure balance air system (Fig 1.3.7). Fuel enters the diffuser through the jet and, when the engine is not running, the fuel level in the diffuser and in the annular space is the same as that in the float chamber. During operation, as the engine speed is increased, the fuel level in the annular space falls, thereby uncovering some of the radial holes. This allows air to flow through the holes into the diffuser, thus lessening the pressure difference acting across the jet and counteracting the tendency of the jet to supply excessive fuel. The diffuser, in addition to fulfilling its primary function, also breaks down or emulsifies the fuel before the fuel is passed into the air stream flowing to the induction manifold.

24. **Slow running jet.** At small throttle openings, the depression in the choke is practically negligible and no fuel flows from the main jets. A separate slow running jet is fitted, therefore, to supply the fuel necessary for slow running. The jet discharges near to the edge of the almost closed throttle (Fig 1.3.8), the strong depression at this point giving the necessary pressure difference. As the throttle is opened, the depression at the throttle edge decreases and that in the choke increases; the slow running jet will reduce its action progressively and the main jet will come into action. The slow running jet is arranged to give the rich mixture required over the idling range. Adjustment is carried out by an adjusting screw, movement of which has the effect of varying the pressure difference action across the jet.

25. **Power jet.** The mixture strength supplied by the diffuser for cruising conditions is too weak for the engine to develop its full power output. To supply the extra fuel necessary to give the desired mixture strength for full power, the size or the number of jets must be increased. Where a variable main jet is fitted, its size is varied by the withdrawal of a tapered needle from the jet orifice. When a fixed main jet is fitted,

an additional jet is brought into operation by the opening of a cam-operated valve. The power jet is illustrated at Fig 1.3.8.

26. **Enrichment jet.** For the short period necessary at take-off until the aircraft is safely airborne, maximum permissible engine power is required. Supercharged engines are designed to develop additional power for this purpose. One method of obtaining this maximum power is to supply the engine with a *very rich* mixture and this is delivered from the enrichment jet which operates in a manner similar to that of the cam-operated power jet (Fig 1.3.8).

27. **Accelerator pump.** If the throttle is opened suddenly, the mixture supplied to the cylinders is momentarily too weak, partly because there is a lag in the increase of fuel flow from the jet and partly because some of the fuel adheres to the walls of the induction system and does not reach the cylinders. An accelerator pump, illustrated at Fig 1.3.9 and which is interconnected to the throttle lever, injects fuel into the airstream to make up for this temporary deficiency. Sometimes a spring-operated delayed action pump maintains the flow for a few seconds after the throttle opening has ceased.

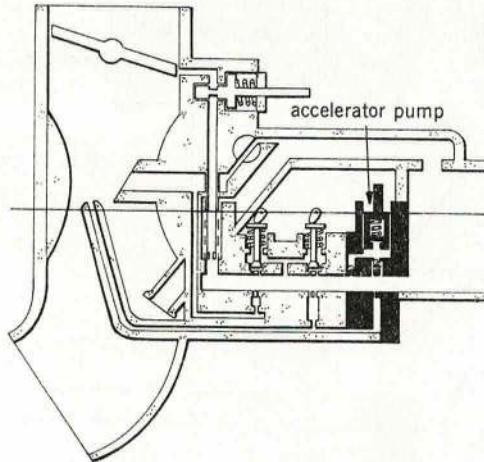


Fig 1.3.9 Accelerator pump

28. **Mixture control.** The density of air decreases with increasing altitude and consequently less weight of air is induced for the same velocity of air through the choke.

Thus, a carburettor using the venturi choke as an air flow meter, delivers a *progressively richer mixture* as the altitude of operation increases. Various methods are employed to correct the mixture strength at altitude. In the smaller engines this mixture control is hand-operated, but on engines of medium and high power output, mixture strength is automatically controlled.

29. The methods employed for correcting mixture strength for altitude are as follows:

a. **Vacuum control.** The pressure difference acting on the jet is induced by connecting the float chamber to the choke via an orifice whose size is varied by the mixture control cock (Fig 1.3.10). By opening the cock, the float chamber pressure can be reduced to give a pressure difference across the jet consistent with the mixture strength required.

b. **Diffuser air bleed.** Air is by-passed, through the mixture control cock, from the pressure balance air system to the top of the diffuser, thus reducing the pressure difference across the jet.

c. **Variable jet.** With increasing altitude, the fuel flow is progressively restricted by a tapered needle valve entering the jet orifice.

30. **Cut-out valve.** To stop the engine, the ignition is switched off. However, because the engine is hot and fuel is still available at the slow running jet, the engine may continue to run. To prevent this occurring, a cut-out valve in the slow running fuel passage is operated to prevent fuel from being drawn into the induction system. This is illustrated at Fig 1.3.10.

31. **Anti-g devices.** When the direction of an aircraft in flight is suddenly changed, forces which oppose the change of direction are imposed upon the aircraft and its component parts. The fuel will be moved in the direction of the opposing force and, in a dive at high speed, the fuel may be momentarily thrown to the top of the float chamber. This interferes with the normal fuel flow, with the result that the engine will be momentarily starved of fuel. Various

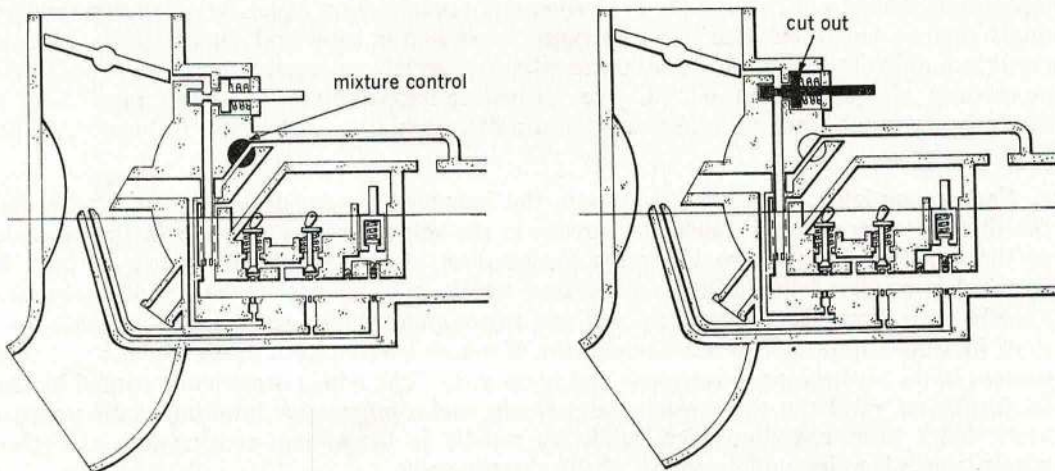


Fig 1.3.10 Mixture control and SR cut-out

'anti-g' devices are incorporated in the carburettor design to assist in maintaining the power output of the engine. The following are examples:

- a. **Float needle 'anti-g' stop.** An adjustable stop fitted above the float needle, in conjunction with a collar on the lower end of the needle, restricts the needle movement and fuel flow during aerobatics to allow the entry of sufficient fuel to keep the engine running at maximum power conditions.
- b. **'Anti-g' ball valve.** This prevents fuel spilling into the choke during unstable flying conditions.
- c. **'Anti-g' stand tube.** Engine cutting due to fuel starvation is prevented by a stand tube which feeds the metering jet from the centre of the float chamber. The carburettor 'anti-g' devices are illustrated at Fig 1.3.11.

Carburettor Heating

32. To ensure satisfactory operation and efficient carburation, some parts of the carburettors (in particular, areas around the throttle, the choke and the air intake) must be maintained at

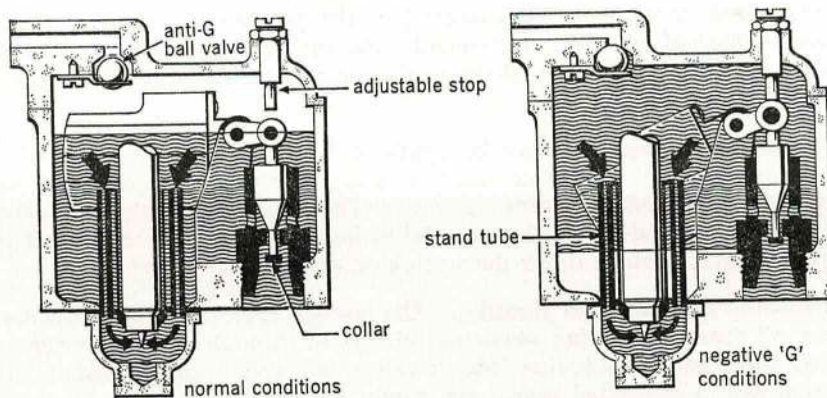


Fig 1.3.11 Carburettor 'Anti-g' devices

temperatures which will prevent the formation and accumulation of ice. Icing encountered by aircraft engines can be divided into two types: carburettor icing and impact icing. Each is formed in a different manner and may occur either separately or together between atmospheric temperatures of -15°C and $+25^{\circ}\text{C}$. Ice formed at temperatures *below* this range is of a sufficiently dry nature not to adhere and accumulate within the carburettor or around the air intake.

a. **Carburettor icing.** The constrictions in the induction system caused by the choke and the throttle valve not only cause an increase in the velocity and a decrease in the pressure of the induced air, but also lower the temperature of the air. Furthermore, as heat is required to convert a liquid into gas, the fuel which is vaporized in the induction system absorbs heat from the induced air and the surrounding metal, resulting in an *additional* drop in temperature. When the temperature of the air is reduced to below 0°C the moisture content in the air begins to precipitate and form as ice. The added constriction caused by the ice formation, results in an increasing air velocity and a progressive lowering of the temperature. With these conditions, ice builds up rapidly in the system causing loss of engine power, rough running and jamming of the throttle valve.

b. **Impact icing.** This form of icing occurs most readily at temperatures between 0°C and -7°C and is caused by rain droplets turning into ice on striking the exposed surfaces of the carburettor. The ice adheres to, and builds up around the air intake, disturbing the air flow, upsetting the mixture strength and resulting in rough running and loss of power; it may even stop the engine.

Protection Against Ice

33. The various methods and devices used to prevent or disperse ice formation in and around the carburettor are as follows:

a. **Gapped ice-guards.** A gapped ice-guard consists of a wire screen mounted in front of the mouth of the air intake. Should the screen become blocked with snow or ice, air can continue to flow into the air intake through the gap left between the screen (ice-guard) and the air intake. This gives protection against impact icing.

b. **Sheltered air-intake.** This device is used in conjunction with a gapless type ice guard. The sheltered air intakes provide an alternative entry for the air and are situated within the engine cowling. They are fitted with shutters, operated either automatically or by electro-pneumatic rams controlled by switches in the pilot's cockpit. The automatically operated shutters are opened by the depression created in the air intake system as the gapless ice guard becomes blocked with ice. Additionally, the sheltered air intake may be designed to draw its air from around hot parts of the engine or coolant radiator thus supplying heated air to the carburettor.

c. **Alcohol injection system.** In some installations, in addition to the heated air system, an alcohol injection system may be fitted and is used as an emergency method of removing ice which may form in spite of the warm air system. The alcohol injection system consists of an electrically driven or hand-operated pump delivering alcohol from a small tank to jets positioned in the air intake, which direct the spirit towards the throttle valves.

d. **Heated throttle housings and throttles.** Carburettor icing can best be prevented by circulating hot oil from the engine scavenge oil system through oil jackets surrounding the throttle bores and through the hollow throttle valves and throttle valve spindles. This method, in conjunction with a controlled heated air supply for the air intakes, is usually adequate and does not require the addition of the alcohol injection system.

Limitations of the Float-Type Carburettor

34. Although the float-type carburettor has been developed over many years to a high state of perfection it has always been realized that this system of air-fuel metering had certain inherent disadvantages. The size of the choke tube for example, is a compromise between the requirements of full throttle power where the least restriction to airflow is necessary, and those of part-throttle operation when the choke must be small enough to provide the required pressure drop with small airflows.

35. With the best possible compromise the choke imposes a restriction at full throttle height, thereby limiting both manifold pressure and power. In addition, the pressure drop across the choke is very sensitive to fluctuations at the air intake and, although pressure balance minimizes the effect upon mixture strength, the shape of the intake and the degree of turbulence cause variations.

36. Another important factor is the effect of aircraft manoeuvres which, due to the effect on the float and needle valve assemblies, cause similar variations in mixture strength. However, as explained, this particular failing has been counteracted by the development of an anti-g float and needle valve assembly.

37. Ice formation on the throttles is another factor which must be considered. In the normal float carburettor, the main fuel discharge into the airstream takes place before the throttle, which is therefore favourably disposed for ice build-up conditions, depending upon prevailing atmospheric conditions and the temperature drop due to atomization of the fuel.

38. To avoid this, the air intake can be heated, and a 'hot' and 'cold' intake system is normally fitted. It must be appreciated, however, that air pre-heating due to density decrease, results in a lesser weight of air (per given volume) being passed to the engine, thereby altering the mixture strength or volumetric efficiency.

39. From the foregoing, it will be evident that in some respects, the float-type carburettor is in need of improvement and to this end, a new system of fuel-flow control was introduced in the form of a fuel injection carburettor which is explained in the next chapter.

Safety Precautions

40. Although there are many safety precautions concerned with the handling of fuel, described in AP3279A, Section 4, Chapter 8, a few very simple, common sense, but most important points to be borne in mind when working on the engine fuel system and components are listed below:

- a. Absolute cleanliness is essential.
- b. Fuel cocks are to be turned OFF before any disconnections are made.
- c. Allow the engine to cool before disconnections are made because of the risk of fire.
- d. All pipelines and apertures are to be blanked off to prevent ingress of foreign matter.
- e. Beware of loose articles dropping into the air intakes/induction manifolds.
- f. Spilt fuel can 'burn' and dry up your skin by dissolving natural oils which result in cracks and infection, the most common being dermatitis. Always mop up spilt fuel.
- g. Never eat, drink or smoke until you have washed your hands after working on the fuel system.
- h. Electrical power should always be switched 'OFF'.
- j. Make sure that all gaskets are renewed when replacing components and that the components, particularly the induction manifold are tightened to the correct sequence to avoid distortion.

- k. Never 'poke about' with wire to remove dirt from fuel jets—always blow them out with compressed air against the direction of flow.
- l. Never use cleaning rag for drying components—use compressed air.
- m. Always have a fire extinguisher at hand.

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