CHAPTER 4

THE FUEL INJECTOR CARBURETTOR AND METHANOL/WATER INJECTION SYSTEMS

Objectives

This Chapter has been written with the aim of helping you to satisfy objectives in the relevent Skills and Knowledge Specifications (SAKS) for the trade in the subject area. When you have studied this Chapter, you will be able to:

a. Describe the operation of a typical gasoline injection system and state the purpose of the components within the system.

b. State the adjustments and checks to be carried out on injection carburettors.

c. State the purpose of a methanol/water injection system.

d. State the safety precautions necessary when handling the methanol/water mixture.

The Fuel Injection Carburettor (Indirect)

2. The fuel from an injection carburettor is injected as a spray under pressure through a spray nozzle to the inlet side of the supercharger impeller. The injector also measures the weight of air being drawn into the engine and adds the required weight of fuel to keep the air/fuel ratio correct at all times. This means that the engine does not rely upon the varying suction at the choke. Other definite advantages are:

a. The fuel is efficiently atomized.

b. The fuel is well mixed with the induced air in the induction manifold and so there is a very good distribution to the cylinders.

c. Float chambers and chokes are eliminated and there is less risk of icing because the fuel is injected downstream of the throttle butterfly valves.

3. The complete fuel injection carburettor consists of the following separate units illustrated at Fig 1.4.1:

a. The fuel control unit (FCU).
b. The manifold pressure control unit.
c. The throttle housing.
d. The fuel discharge assembly.

We shall now discuss each unit and the variations which affect the fuel flow.

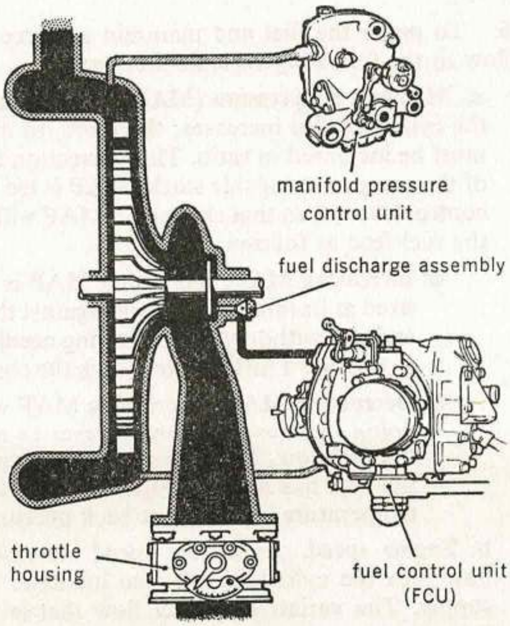


Fig 1.4.1. A fuel injection system

The Fuel Control Unit (Fig 1.4.2 pull-out drawing)

4. The FCU, which is illustrated at Fig 1.4.2, meters the fuel to the fuel discharge assembly and consists of:

a. An engine driven gear type pump (25) that has a capacity greater than the maximum engine demand.

b. A pump relief valve (15) which ensures that the fuel pump maintains the constant fuel pressure set by the manufacturers.

c. A fuel metering needle valve (8) and operating mechanism (4). The needle valve, moving in a fixed orifice, adjusts the fuel flow to changes in manifold pressure, air temperature and exhaust back pressure.

d. An engine driven centrifugal impeller (26) which generates a fuel pressure drop that is related to engine speed.

e. A diaphragm controlled pressure regulating valve (9). This valve maintains the pressure difference across the metering valve (8) generated by the impeller and so adjusts the fuel flow for changes in engine speed.

f. A fuel cut-off valve for stopping the engine (2).

g. An accelerator pump unit (16).

5. **Operation.** Fuel from the spur gear pump (25) enters the chamber containing the fuel metering valve (8). The fuel flow is metered through the main metering orifice and is delivered through the pressure regulating valve (9) to the fuel discharge valve (1) which is positioned at the eye of the supercharger impeller. Assuming that the difference in fuel pressure across the main metering orifice remains the same, then the fuel flow will vary with the projection of the needle valve. The fuel metering valve (8) is moved in the main metering orifice by the combined action of the capsule stack (7) and a Bourdon tube (31). The main section of a capsule stack is connected internally to engine manifold pressure so that the length of the stack will vary with manifold pressure and, acting on the lever pivoting on the Bourdon tube (31), will adjust the needle to give the correct flow relative to the manifold pressure obtained. A rise in manifold pressure withdraws the needle, giving the required greater fuel flow, and *vice versa.*

6. To meter the fuel and maintain a correct mixture strength it is necessary to relate the fuel flow to the following variable factors:

a. **Manifold air pressure (MAP).** When manifold air pressure rises, the weight of air entering the cylinders also increases; therefore, to maintain a correct mixture strength, the fuel supply must be increased in ratio. This correction is made by the action of MAP upon the bellows (7) of the composite capsule stack. MAP is led to the inside of the capsules (7) which act upon the control lever (4) so that changes in MAP will reset the metering needle (8) to increase or decrease the fuel feed as follows:

- **Increasing MAP.** Increasing MAP is fed to the inside of the capsule stack which, being fixed at its inner end, moves against the control lever. The control lever pivots at its lower end and withdraws the metering needle from the metering orifice by the amount necessary to provide a fuel flow to match the change in MAP.
- **Decreasing MAP.** Decreasing MAP will cause the capsule (7) to reduce in length and, in doing so, cause the control lever to move the metering needle into the orifice to reduce the fuel flow. The capsule stacks (6) and (7) are balanced so that the pressure fuel inside the unit has no effect upon the position of the metering needle. Thus, at any given air temperature and exhaust back pressure the fuel flow is proportional to the MAP.

b. **Engine speed.** As engine speed increases, at constant manifold pressure, the rate of air flow into the cylinders will also increase. This will require proportional increase in the fuel supply. The variation in fuel flow that is required for a change in rev/min, with the manifold pressure constant, is effected by varying the difference between the fuel delivery pressure to, and the fuel outlet pressure from, the main metering orifice. The flow across an orifice varies with the pressure drop. The fuel delivery pressure is maintained at a constant predetermined pressure above atmospheric pressure by the fuel pump (25) and its relief valve, but the fuel outlet pressure from the metering orifice varies with the pressure changes at the eye of the impeller. The pressure drop at the eye of the impeller will vary with its speed; in this case, the faster the engine runs the greater will be the pressure drop. The prevailing pressure at the impeller eye is applied to one side of the diaphragm (14) in the pressure regulating housing. This will cause the pressure regulating valve (9) to control the fuel flow out of the housing to maintain the other side of the diaphragm at an equal pressure. Thus, as the main metering orifice will be the same as the impeller eye pressure, the pressure drop across the orifice will vary proportionally with engine speed.

c. **Air Temperature.** To correct the fuel flow for changes in the air temperature, a temperature bulb (30) is fitted in the air intake and is connected by capilliary to the Bourdon tube (31) at the end of the metering needle valve operating lever. An increase in temperature at the air intake reacts on the contents of the Bourdon tube to straighten it out, and the lever, pivoting about the capsule pin, moves the main metering needle valve into the orifice to restrict the fuel flow. Thus, an air temperature rise, reducing the weight of air passing to the cylinders, brings about an automatic reduction in the fuel supply. A fall in air temperature has the reverse effect.

d. **Exhaust back pressure.** As altitude increases, there will be a decrease in the atmospheric pressure which is resisting the out-flow of the exhaust gases from the cylinders. This will result in a more efficient scavenging of the cylinders on the exhaust stroke and a subsequent increase in the mass flow into the cylinders on the following induction stroke. A decrease in exhaust back pressure must, therefore, be compensated by an increase in fuel flow and vice versa. To give the required variation, the outer section of the capsule stack (5) is vented to atmosphere. With a drop in atmospheric pressure, as at altitude, the vented stack will contract and the lever, pivoting at the Bourdon tube, will move the needle valve out of the metering orifice to give a greater fuel flow. Similarly, with a rise in atmospheric pressure, the vented capsule will expand and move the lever to close the needle valve and restrict the flow. One psi change in exhaust back pressure requires only one-fifth of the variation in fuel flow needed for a change of 2 in Hg in manifold pressure. Coupling the four exhausted capsules with the vented capsule brings about a corrected proportional needle movement between the manifold pressure and back pressure section of the capsule stack for similar changes in pressure.

Accelerator Pump (Fig 1.4.2)

7. The accelerator pump supplies the extra fuel necessary to produce a smooth acceleration without 'flat spots'. The additional fuel is supplied to the engine over a period of time that varies with the throttle lever movement. The throttle lever is directly linked to a piston (16) in the main fuel chamber. Under steady running conditions, the accelerator pump valve and diaphragm assembly (21, 22) shuts off the accelerator delivery duct to the accelerator jet (27) and the fuel discharge nozzle. When the throttle is moved forward, the resulting movement of the acceleration piston reduces the pressure above the accelerator pump diaphragm and the valve opens, allowing fuel to by-pass the main metering orifice. A designed clearance permits fuel to leak gradually past the piston to rebuild the pressure above the diaphragm and allow the valve to close. The period of time that the valve remains open will depend on the initial throttle movement, the maximum period being between 3 and 5 seconds. The flow rate from the pump during this period depends on the size of the accelerator pump jet (27). When the throttle lever is closed, a flap valve (17) on the piston prevents a hydraulic lock by allowing fuel to escape from above the diaphragm (21) to the compartment (18).

Fuel Cut-off Valve (Fig 1.4.2)

8. The fuel cut-off valve (2) is a spring-loaded plunger and seating, positioned in the outlet passage of the FCU. The spring holds the plunger off the seating, and an operating lever is connected to the cockpit. When the plunger is depressed, it seals off the fuel delivery to stop the engine.

Slow Running and Enrichment Valve and Jets (Fig 1.4.2)

9. Although the main metering needle is tuned to supply the correct mixture strength, because of manifold pressure reversal characteristics of the engine, a certain amount of richness is obtained at slow running. This is adjusted by the slow running jet (28) to obtain the correct mixture. When the slow running and enrichment valve (12) is positioned at slow running the jet bleeds fuel from the delivery side of the metering orifice back to the pump inlet. This tends to lower the pressure in the compartment (10) and closes the pressure regulating valve (9) sufficiently to correct the slow running mixture. The slow running and enrichment valve (12) is linked to the pilot's throttle lever. When this lever is moved beyond the maximum economical cruising point, the enrichment valve opens and allows the enrichment jet (29) to feed fuel from the compartment (18) to the compartment (10). This allows extra fuel to pass through the valve (9) and provide the richer mixture required at higher engine powers.

Manifold Pressure Control Unit (Fig 1.4.3 a, b, c, and d)

10. The manifold pressure control unit forms the link between the pilot's throttle lever and the butterfly throttles contained in the throttle housing. The unit maintains a stable manifold pressure for a given throttle lever position up to full throttle height irrespective of the altitude of the aircraft. It does not provide a direct mechanical link, except at low power and during a manifold pressure control unit failure.

11. The unit consists of the following components:

a. A variable datum cam and layshaft assembly.

b. A manifold pressure responsive capsule assembly.

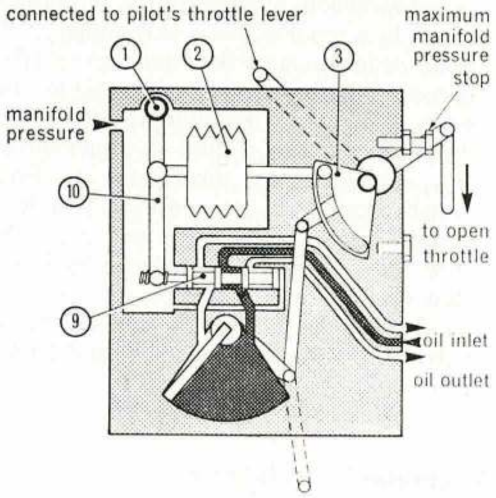
c. A servo relay valve.

d. A vane-type servo motor.

e. A variable fulcrum rocking lever arrangement.

12. **Operation.** When the pilot's throttle lever is moved from slow running to the take-off position, the variable datum cam illustrated at Fig 1.4.3a (3) displaces the capsule assembly (2) bodily, and slides the relay valve (9) to its guide via the lever (10) which rotates about the pivot (1).

13. The relay valve meters pressurized oil to the appropriate side of the servo motor



a Slow-running

LEGEND FOR FIG.1.4.3a,b,c and d

1 Pivot

2 Capsule assembly

3 Variable datum cam

4 Rocking lever

5 Servo vane

6 Eccentric

7 Manifold pressure control layshaft

8 Return spring

9 Relay valve

10 Lever

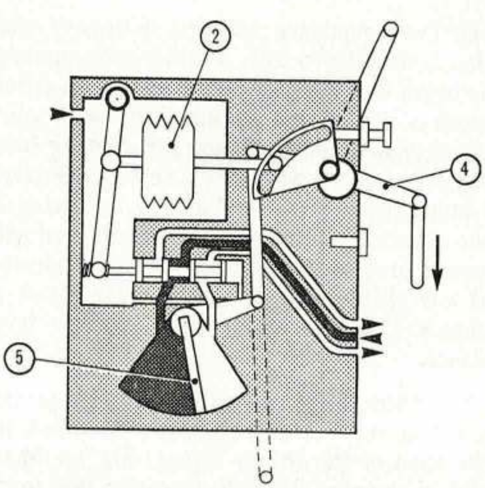
Fig 1.4.3a Manifold pressure control unit (slow running)

vane illustrated at Fig 1.4.3b (5) which, in turn, moves and opens the throttle via the rocking lever (4). The consequent manifold pressure rise due to engine speed increase, is applied to the capsule (2) and compresses it sufficiently to return the relay valve to the neutral position. This prevents further vane movement and stabilizes the manifold pressure at the required value.

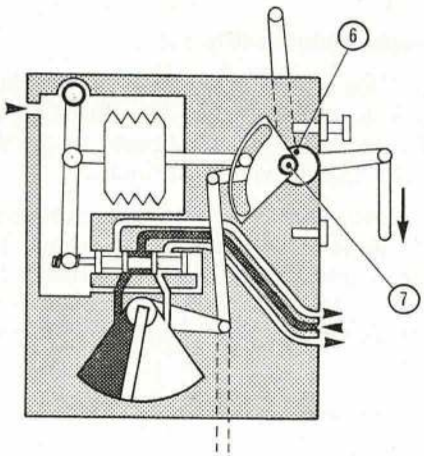
14. When the pilot's throttle lever is moved back to the cruising setting illustrated at Fig 1.4.3c the cam displaces the capsule, lever and valve in the reverse direction, and the servo vane closes the throttle sufficiently to adjust the manifold pressure.

15. The action of the manifold pressure control unit when atmospheric pressure is decreasing at a fixed throttle lever setting (such as may occur during a climb at altitude) is illustrated at Fig 1.4.3d overleaf. Under such conditions, the resultant gradual reduction in induction manifold pressure causes the capsule to expand slowly, with the result that the throttle opens progressively to maintain the manifold pressure at the selected value. So long as the engine oil is supplied under pressure to the manifold pressure control unit, the latter will maintain the manifold pressure at a steady value for any given throttle lever setting, from ground level to the full throttle height for the manifold pressure selected.

16. The relationship between selected manifold pressure and layshaft angle depends on the profile of the variable datum cam (3), and the cam is designed to give smooth and progressive adjustments of power output. To obtain efficient engine control over the slow running range, limited mechanical operation of the throttles is provided at the lower end of the manifold pressure curve.



b Throttle lever at take-off



c Throttle lever at cruising

Fig 1.4.3b & c Manifold pressure control unit (take-off and cruising)

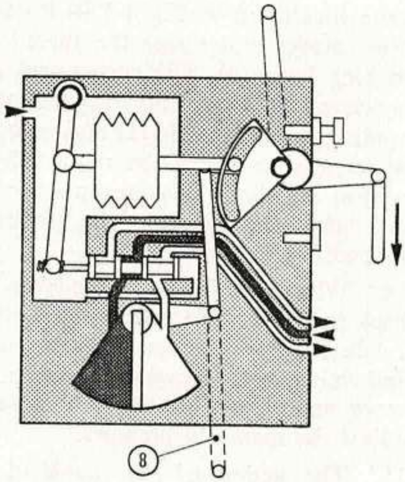
17. To achieve this, the lower end of the cam is designed to select manifold pressure much lower than the minimum produced by the engine under low speed conditions. This maintains the servo vane against the slow running stop and the throttles are operated mechanically due to the action of the eccentric. Fig 1.4.3c (6) and the rocking lever, Fig 1.4.3b (4) refer.

18. When the manifold pressure control layshaft, Fig 1.4.3c (7) is turned from slow running, sufficient to select the cam position and the engine manifold pressure, the manifold pressure control automatically takes over.

19. When the servo vane moves, the rocking lever pivots on the eccentric to transmit vane displacement in the throttles. If, for any reason, the manifold pressure control does not operate

and the servo vane remains stationary, then that end of the rocking lever may be regarded as being fixed. Under such conditions, movement of the pilot's throttle lever will rotate the eccentric and displace the rocking lever about its connections to the servo vane lever. Limited movement is therefore imparted to the throttle, sufficient to provide enough power for maintaining control of the aircraft at low altitudes. This movement is about 15 degrees for the full pilot's throttle lever travel.

20. When the relay valve is in its neutral position, it passes just sufficient oil to balance the load of the return spring, Fig 1.4.3d (8) and to prevent sluggish operation due to oil cooling and congealing. A bleed hole through the vane allows a small constant circulation of oil through the unit.



d Increase in altitude at cruising throttle setting

Fig 1.4.3d Manifold pressure control unit (altitude)

Throttle Housing (Fig 1.4.4)

21. This unit is a twin-bore, aluminium casting that houses two throttles. Hollow compartments around the bores are closed by end covers and flat plates to form oil jackets. The unit is flanged at the tip for fitment to the underside of the engine rear cover and at the bottom for attachment of the aircraft intake.

22. Both throttles are of the conventional type and have external cavities which communicate with the interior of the tubular shaft. The throttles are secured to the shaft by four bolts, two to each throttle, and these also secure the four oil baffles within the shaft. Three oil-impregnated bushes fitted in the throttle housing provide the bearings for the shaft, the ends of which protrude through the housing end covers and carry an operating lever and pointer.

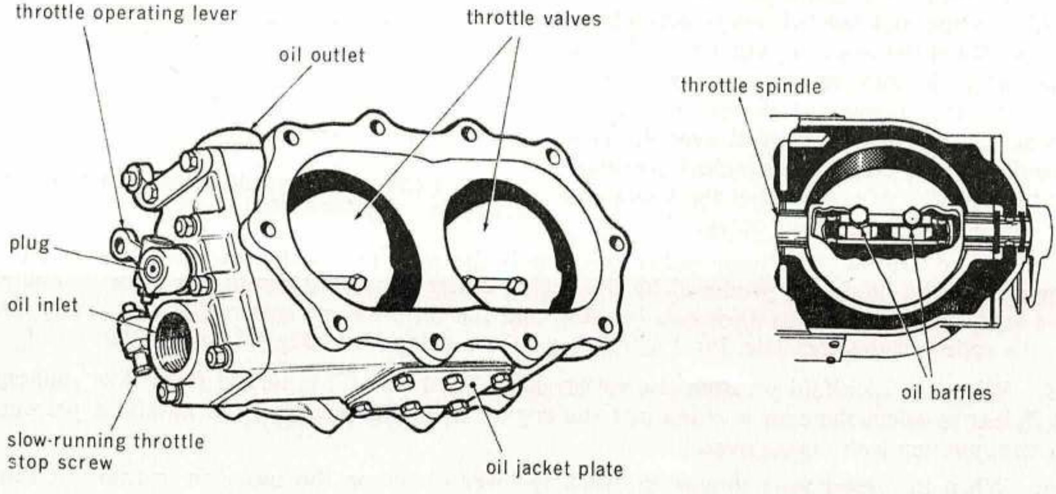


Fig 1.4.4 Throttle housing

23. Oil sealing of the moving parts is achieved by plugging the ends of the shaft. Eight ring seals are fitted. Four of these are housed in recesses formed in the two end covers and the other four are fitted into similar recesses in the shaft bores of the throttles.

24. Accommodation for a relief valve is made on the end cover. The relay valve is a flat spring-loaded hinge plate that covers a hole through the joint faces of the end cover. This valve prevents oil pressure build up when cold starting the engine and allows oil to by-pass the throttles direct to the outlet union.

25. **Operation.** Hot oil from the engine scavenge pump is circulated round the jackets into the throttles to prevent ice formation. The oil from the engine is piped into the end cover and enters the throttle shaft through two holes in the shaft mid-way between the ring seals in the end cover. Baffles, fixed in the throttle shaft, divert the oil through cavities in both throttles. The oil is then passed into the other end cover and circulated around the jackets to the outlet union. An example of the throttle housing is illustrated at Fig 1.4.4.

Fuel Discharge Assembly Unit (Fig 1.4.5)

26. This assembly is housed in the engine rear cover. It consists of a spring loaded diaphragm-operated valve fitted in a tubular brass housing. The diaphragm is located between the flange face of the housing and a cover plate. Of the two chambers, the outer one accommodates a spring and is open to atmosphere through a small vent hole in the cover.

27. The other chamber, in which the valve is situated, communicates with the fuel outlet pressure in the FCU via a short interconnecting pipe. The pressure of the fuel acting on this side of the diaphragm, against the combined load of the spring and atmospheric pressure, operates the valve. The fuel discharge valve is adjusted to maintain a fuel pressure of approximately 15 psi (1·034 bars) above atmospheric pressure.

28. The fuel discharge valve maintains constant pressure above atmospheric pressure at the outlet side of the pressure regulating valve. This overcomes any adverse effects that a change in induction manifold pressure might tend to produce. An illustration of the fuel discharge assembly is illustrated at Fig 1.4.5.

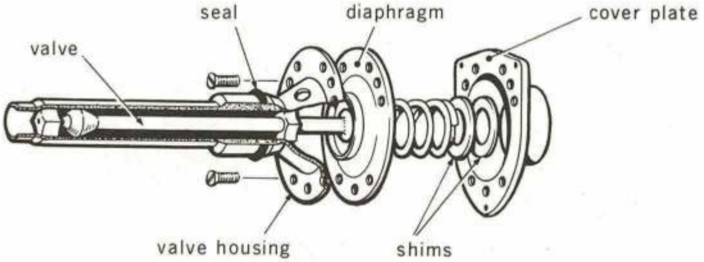


Fig 1.4.5 Fuel discharge assembly

Priming and Starting

29. During starting and initial running of the engine, the metered fuel pressure is not sufficiently high to activate fully the main fuel discharge valve, and the engine speed is insufficient to ensure complete atomization of the fuel. To facilitate starting, therefore, the engine is provided with a fuel priming system incorporating an electrically operated solenoid valve mounted on a bracket attached to the FCU. It is electrically operated from the cockpit and by-passes the pump of the FCU and delivers the fuel direct to the priming spray nozzle located in the supercharger inlet passage.

Adjusting the Fuel Pressure

30. **Preparation.** The correct fuel pressure setting figures for the Hobson AL (Alvis Leonides) injection carburettor are found in the engine Air Publication. The desired fuel pressure is 27 psi (1·86 bar) but the injection carburettor gives satisfactory results with fuel pressures between 25 psi (1·72 bar) and 29 psi (2·00 bar). Once set correctly, the fuel pressure is unlikely to cause any trouble. However, the fuel pressure should be tested and adjusted as necessary in the following circumstances:

- After engine installation.
- Preparation for use after storage.
- After fitting a fuel control unit.
- Unidentified abnormal engine running.

31. **The fuel pump and pressure relief valve.** A spur gear fuel pump is built into the fuel control unit, with a relief valve adjustment that is situated inside the fuel control unit casing. To gain access to the pressure relief valve adjustment, a combined relief valve and accelerator valve cover must be removed. The combined cover is fitted at the base of the fuel control unit and the cover should be removed carefully because it retains the accelerator valve, the diaphragm spring and the diaphragm. Careless removal of the cover may result in damage to these parts—including dropping or even loss of the diaphragm spring. Whilst removing the retaining screws, it is necessary to hold the cover firmly in position and then, as the cover is withdrawn, you must catch and remove the diaphragm spring which is fitted between the diaphragm and the main body of the FCU (Fig 1.4.6).

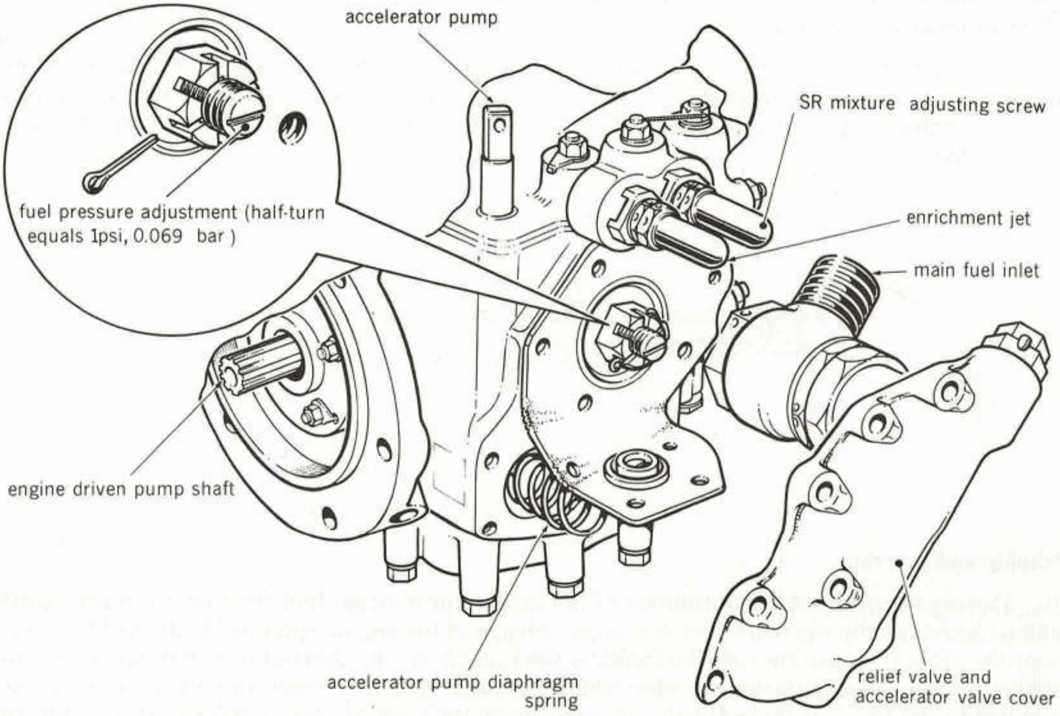


Fig 1.4.6 Adjusting the fuel pressure

32. Removing the combined cover exposes the fuel pressure relief valve adjustment which is a slotted screw secured to a locknut by a split pin (Fig 1.4.6). To adjust the fuel pressure it is necessary to remove the split pin and turn the slotted adjusting screw as follows:

- Clockwise to increase fuel pressure.
- Anti-clockwise to decrease fuel pressure.

One complete turn of the adjusting screw alters the fuel pressure by approximately 2 psi (0·138 bar) and the adjuster should be turned in or out by an amount which provides the desired correction to fuel pressure. It should be appreciated that a pressure test cannot be carried out until the adjuster is locked and the cover has been replaced. Therefore, considerable care is needed in assessing the amount of alteration needed and also in making the adjustment itself.

33. **Testing and adjusting the fuel pressure.** To obtain accurate fuel pressure readings, before and after adjustments, a master pressure gauge is fitted to the pressure point which normally feeds the fuel pressure transmitter. It is essential that the pipe used between the pressure pick up point and the master gauge is of a length which permits the gauge to be positioned where it can be read easily when the engine is running.

34. Start and warm up the engine, switch off the fuel booster pump, run the engine at maximum continuous rev/min and record the fuel pressure shown on the master gauge. If the pressure recorded is 27 psi (1·86 bar) ± 2 psi (0·138) at maximum cruising rev/min, then no adjustment is needed, although the fuel pressure may drop to 20 psi (1·38 bar) at idling speed. However, if the fuel pressure is outside these limits, adjustment is necessary and the following work is to be carried out:

- Stop the engine.
- Remove the relief valve and accelerator valve cover plate.
- Remove the split pin from the relief valve adjuster (Fig 1.4.6).
- Turn the adjusting screw by the amount necessary to correct the fuel pressure.
- Re-lock the adjuster screw with a new 1 in × 1/16 in split pin. (The legs of the pin are bent back until they are flush with the sides of the locknut).
- Replace the diaphragm spring; carefully replace the cover plate and refit the securing screws.
- Re-start the engine and confirm that the fuel pressure is correct.
- Complete the appropriate documentation.

Adjusting the Manifold Air Pressure

35. **The control unit.** The internal linkage of the manifold air pressure (MAP) control unit is pre-set by using special equipment and once set it must not be disturbed. The pilot's throttle lever is connected to a variable datum cam, in the MAP control unit, so that when the maximum MAP is correct, manifold air pressure will also be correct at all other power selections. Therefore, an adjustment is provided for maximum (take-off) MAP and this is the only adjustment permitted.

36. **Adjusting the MAP.** The correct manifold air pressure for a particular engine is found in the engine Air Publication but all Hobson AL injection carburettors have the same type of MAP adjustment (Fig 1.4.7).

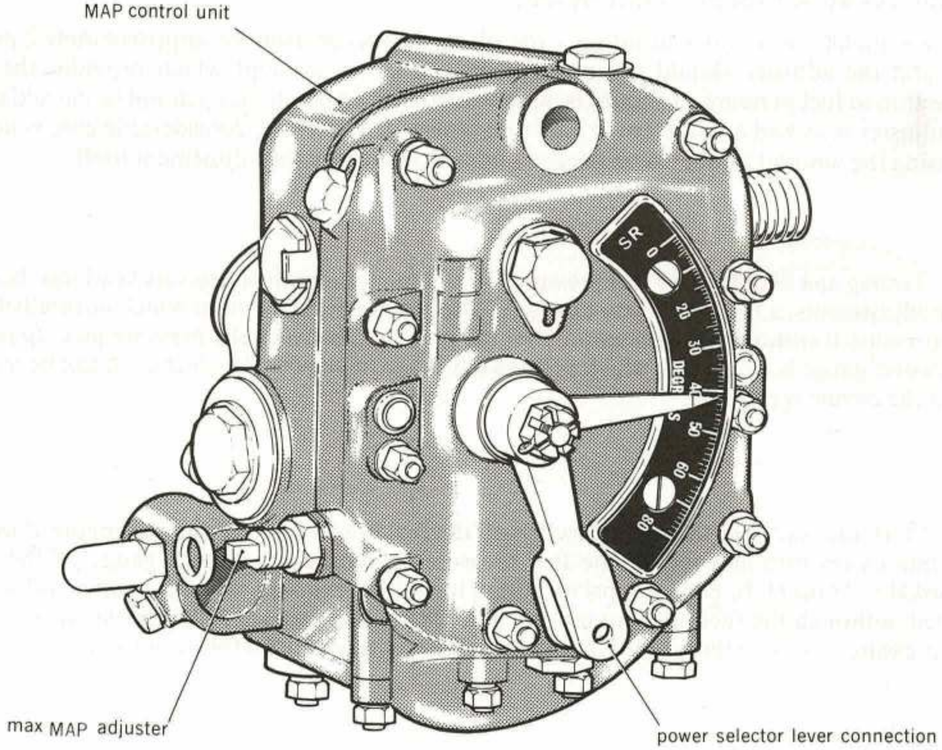


Fig 1.4.7 Manifold air pressure adjustment

To obtain a correct manifold air pressure reading, it is important that the propeller fine pitch setting is correct and that the propeller control unit is selecting fine pitch so that the engine achieves its correct maximum speed. The engine is started and allowed to warm up to its normal operating temperature and then maximum power is selected. Allow the engine to stabilize and record the engine rev/min and the manifold air pressure. Do not keep the engine running at maximum power for more than a few seconds and do not allow cylinder head temperature to exceed the recommended maximum value. If necessary, throttle back, allow the engine to cool and then advance the throttle to max power a second time. If the MAP is incorrect, check the pressure lines, clean the fuel trap, and have the pressure gauge tested before altering the pressure adjustment. However, if no fault is found, adjust the maximum MAP by undertaking the following work:

a. Remove the domed cover from the MAP adjuster screw (Fig 1.4.7).

b. Slacken the locknut and turn the adjuster screw:

- *In* (clockwise) to reduce the maximum MAP.
- *Out* (anti-clockwise) to increase the maximum MAP.

(One complete turn of the screw will alter the MAP by 2 in Hg).

c. Tighten the locknut and then run the engine at maximum rev/min to check the maximum MAP. Repeat b and c until max MAP and rev/min are correct.

d. Complete the appropriate documentation.

Note. Excessive MAP may cause serious damage to the engine; therefore, do not continue to advance the throttle if the MAP rises above the maximum permitted value.

Adjusting the Idle Mixture Strength and Rev/Min

37. **General notes.** The engine should idle smoothly and consistently at an idle speed which should be between 600 and 750 rev/min. If the engine idling speed is outside this range, it must be reset to bring the rev/min into the recommended range. In this respect, it should be noted that the idling speed of the engine is affected by the mixture strength and, therefore, the mixture strength and rev/min may need to be adjusted together. Also, the engine should be in good condition with correctly set valve clearances; the ignition timing should be correct and the engine should achieve its correct maximum rev/min at the specified manifold air pressure (MAP).

38. **Idle speed mixture setting.** Run the engine until it reaches normal operating temperature and adjust the throttle stop to give 700 rev/min. The throttle stop screw is on the starboard side of the throttle housing; screwing it *in* increases idle rev/min and screwing it *out* decreases idle rev/min (*see* Fig 1.4.9). Thoroughly warmed up and with the idling speed set to 700 rev/min, the engine is now ready for slow running (idle) mixture adjustment.

39. Remove the domed cover nut from the mixture adjusting screw and free the locknut (Fig 1.4.8). Start the engine and run it at a fast idle speed for about one minute; throttle back to idle rev/min and confirm that the rotary disc valve has moved into the slow running position shown on its quadrant.

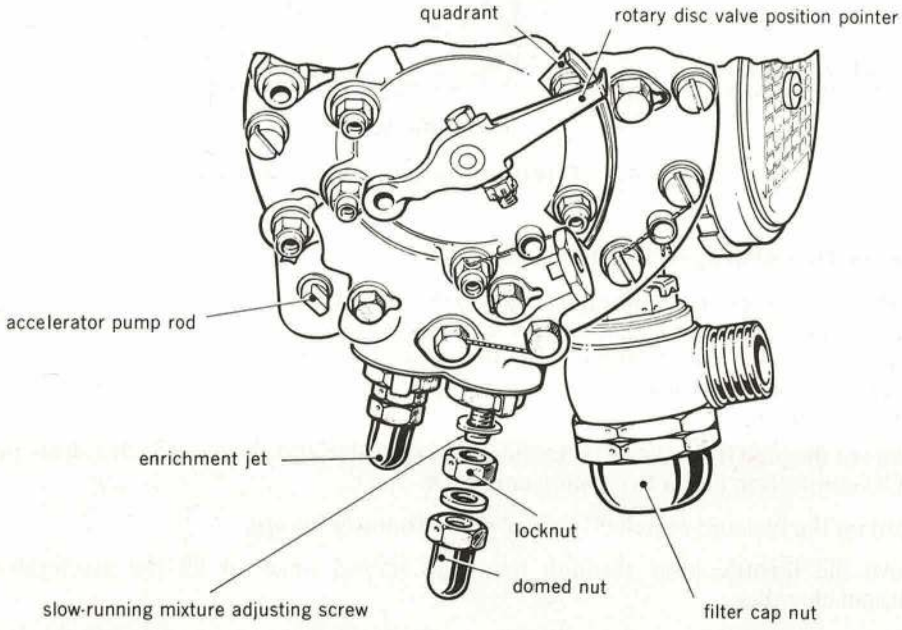


Fig 1.4.8 Slow running mixture adjustment location

Alter the mixture strength by small amounts—out to weaken, in to richen—until the engine idles smoothly, and good acceleration is obtained when the throttle is opened quickly from idle to max rev/min. After each alteration of mixture strength the idle speed should be reset to 700 rev/min.

40. When the mixture strength is correct and the idling speed is satisfactory, lock both the throttle stop and the mixture adjusting screw, replace and lock the domed nut on the mixture adjustment and complete the appropriate documentation.

Note. After adjusting the position of the throttle stop it may be necessary to correct the length of the external control rod which connects the manifold air pressure control to the throttle valve (Fig 1.4.9). On no account alter the length of the rod between the MAP control unit and the cross shaft.

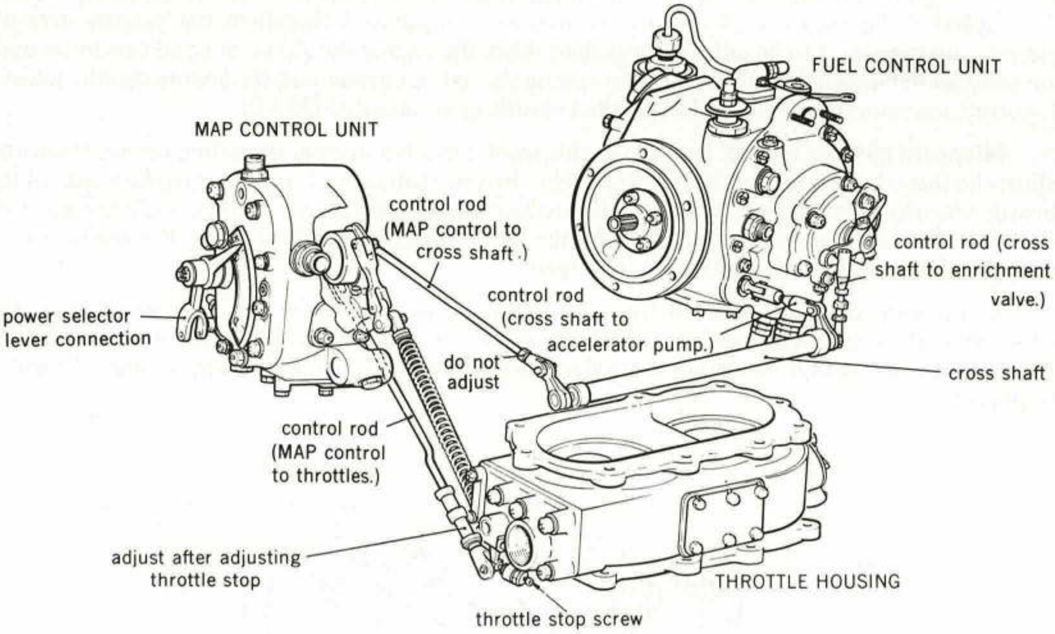


Fig 1.4.9 Throttle stop and external linkage

Inhibiting and De-inhibiting an Injector Carburettor

41. **General.** To keep the diaphragm of the carburettor serviceable during a period of idleness, it is important that either the carburettor is kept full of fresh fuel or that it is inhibited. The most effective way of keeping the unit full of fresh fuel is to run the engine for a few minutes every week. When this is not possible with an installed carburettor, then the FCU should be primed with fuel in the following manner:

a. Remove the pipe from the FCU to the discharge valve and replace it with a drain pipe from the FCU connection into a two gallon container.

b. Turn on the fuel and switch on the LP pump (booster pump).

c. Move the throttle lever through its range several times to fill the accelerator pump diaphragm chamber.

d. When approximately a gallon of fuel has collected in the container beneath the drain pipe, turn off the fuel and switch off the LP pump.

e. Close the throttle. *The throttle lever should not now be moved until repriming or on engine starting.*

f. Remove the drain pipe and fit original pipe.

42. **Inhibiting.** When the engine is expected to be out of service for some time, then the FCU must be completely drained and inhibited with storage oil during the engine inhibiting operation. This can be done without removing the unit from the engine as follows:

a. Remove the pipe connecting the fuel control unit to the discharge valve and attach a drain pipe from the FCU connection to a two gallon container.

b. Disconnect the main fuel pipe to the FCU.

c. Remove the plug in the accelerator pump jet assembly.

d. Remove the two 2 BA set bolts marked 'D' from the pressure regulating valve diaphragm covers and the two similarly marked bolts on the accelerator and relief valve cover.

e. When all the fuel has drained, replace the plug and the four bolts.

f. Connect a two gallon tank fitted with a pressure gauge and hand pump to the main fuel inlet. Fill the tank with inhibitor fluid and operate the hand pump to maintain a pressure of 20 psi (1·379 bars) until oil emerges from the drain pipe fitted to the FCU outlet.

g. Exercise the throttle lever to pass oil to the accelerator pump diaphragm.

h. Turn the engine through a few revolutions by hand to coat the gears of the fuel pump with oil.

j. Detach the drain pipe and refit the original pipe connecting the FCU and the discharge valve. Operate the hand pump to ensure oil fills the discharge valve.

k. Remove the oil tank and pipeline and fit a blank to the fuel inlet union of the FCU.

43. Where carburettors are not installed and are not expected to be used for some time they are inhibited in a similar manner to that described in para 42, except that all connections must be sealed off with blanking plugs; clean engine oil must be applied to the joints and surfaces of the external linkage. The MPCU capsule chamber should be drained and the chamber filled with inhibiting oil. All other external and internal surfaces not protected against corrosion must be sprayed with a protective coating. The throttles must be wire locked in the closed position and all exposed joint faces protected with blanking covers. The injector is then wrapped in grease-proof paper and placed in a special container.

44. **De-inhibiting.** When a carburettor that has been inhibited is required for engine running, the inhibiting oil must be replaced with fuel. It is easier to drain the inhibitor before the carburettor is fitted, but in case of a carburettor already installed the following method may be used:

a. Remove the inlet and outlet fuel pipes to the FCU and allow the oil to drain into a container.

b. Attach a drain pipe to the outlet connection and feed the pipe into a two gallon container. Refit the main fuel inlet pipe.

c. Make sure the magneto switches are OFF.

d. Turn the fuel ON and switch the LP pump ON.

e. Turn the engine by hand until all the oil has been flushed through the FCU and the container is full. Turn OFF the fuel and switch the LP pump OFF.

f. Drain the MPCU capsule chamber of inhibiting oil and fill with engine oil to the correct level.

g. Close the throttle, turn ON the fuel, switch ON the LP pump for 30 seconds to prime the carburettor and the engine is ready for starting.

45. More detailed information on this subject is contained in AP4471A Vol 1 Pt 2 Sect 3. Remember that cleanliness is absolutely essential.

Methanol-Water Injection Systems

46. Earlier in this chapter, when discussing manifold pressure, it was stated that the power output of the engine will increase as manifold pressure is raised, but eventually the corresponding increase in cylinder head temperature would have to be curtailed to prevent detonation. This can be achieved by injecting a methanol and water mixture into the induction manifolds, thus permitting an increase in the maximum manifold pressure. Although methanol-water injection systems are limited in use on piston engines in the Royal Air Force today, some background knowledge on the subject will not be amiss.

47. The injection of water under pressure can be used with good effect to reduce charge temperatures and increase the power output. Air cooled engines show a greater response than liquid-cooled to this method, probably because of the greater scope for cooling of the cylinder head and inlet ports. For use at high altitudes, the water in the tank, pipelines and atomizer jets must be rendered non-freezing by the addition of some suitable substance such as methanol.

48. An increase in power can be obtained by gearing up the speed of the supercharger to give a manifold pressure higher than the normal maximum permissible and subsequently reducing the charge temperature by the injection of methanol-water to give the maximum weight or density of charge entering the cylinder within the detonation limits.

49. On an engine in which the manifold pressure is limited by the position of the throttles of the supercharger inlet, additional power can be obtained by an increase in manifold pressure through the operation of a manifold pressure override control; the charge temperature is then maintained within the detonation limits by the injection of methanol-water. This method is confined mainly to power increase at take-off and 'all-out' low level conditions. In normal flight, however, an increase in power will be gained by the use of this system, provided that the aircraft is not above the maximum manifold pressure full-throttle height. Above this height, the use of methanol-water injection may cause a slight drop in manifold pressure and the power increase becomes progressively less with increase in altitude.

50. The increase in manifold pressure which can be permitted to any given engine is limited by the following factors:

a. The mechanical strength of the engine.

b. Detonation limits.

c. The characteristics of the supercharger and the strength of the supercharger drive shaft.

51. The mechanical limitations are inherent in the engine design and show themselves in the cylinder assembly and the main bearings. Detonation is the result of high cylinder head temperatures and may be suppressed by the use of high octane fuel and by injection into the induction manifold of such liquids as water and methanol.

52. The limitations imposed by an inadequate supercharger compression ratio may be overcome by increasing the supercharger gear ratio in order to give a higher impeller tip speed. However, the power required to drive the supercharger is directly proportional to the manifold pressure and, on some engines, the strength of the supercharger shaft becomes critical before the mechanical strength of the cylinder assembly.

Principles of Methanol-water Injection

53. The primary effect of the injection of methanol-water fluid into an internal combustion engine, additionally to gasoline, is to reduce the temperature of the air entering the cylinders and so

to increase the charge density. This charge cooling results from the evaporation of the liquid, heat being extracted from the air to provide the necessary latent heat of evaporation.

54. This evaporative cooling effect is present when gasoline fuel is used, complete evaporation of a 20% over-rich mixture causing a drop in air temperature of approximately 25%. A richer mixture provides a greater cooling effect, but the power loss due to the displacement of useful air by excess gasoline vapour exceeds the gain due to the greater evaporative cooling effect on the charge. The cooling effect of injected methanol is approximately seven times that of 20% over-rich mixture. Water has approximately three times the cooling effect of methanol. These ratios are those assuming the maximum power gain from the injection of fluid.

55. In passing from the induction manifold into the cylinder, the charge will absorb heat from the surrounding metal, and the effective weight of charge will be governed by its temperature after entering the cylinder. A secondary effect of the injection of methanol-water is the cooling of the piston and cylinders.

56. When methanol-water liquid is injected into the engine induction system in small quantities, it will evaporate. If the rate of injection is increased, however, a point will be reached at which the air is saturated with methanol-water vapour, any greater amount of methanol-water being unable to evaporate.

57. The time available for the evaporation of the methanol-water in the induction system of an engine is limited. Consequently, when the rate of injection is such that the methanol-water is present in quantities almost sufficient to saturate the air with vapour, a certain amount of liquid methanol-water will, in fact, be passing through the induction system, the actual proportion of liquid vapour depending upon the degree of atomization of the methanol-water spray.

58. The presence of liquid methanol-water in the induction system can cause uneven running. If the liquid is evenly distributed between the cylinders, it will do no harm and will cool the charge in the cylinder during the induction stroke. However, if the liquid is unevenly distributed between the cylinders, rough running is likely to result, since in addition to variations in the methanol-water/gasoline/air ratio, there may be variations in the composition of the methanol-water/gasoline mixture reaching different cylinders.

59. The limiting methanol-water/gasoline/air ratio to give maximum indicated horse power is that which gives saturation conditions at the end of the induction stroke.

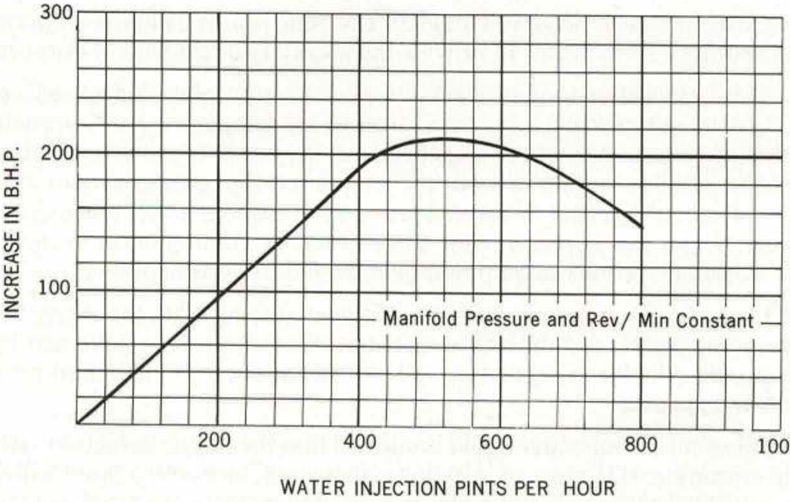
A graph showing the effect of water injection in relation to Brake Horse Power, together with one which shows the fuel consumption/rate of injection, are illustrated at Fig 1.4.10 overleaf.

Methanol-Water Injection System

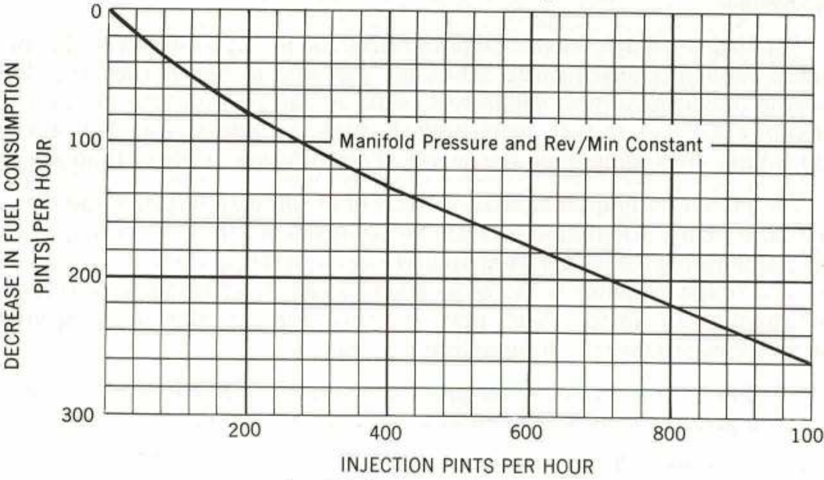
60. An aircraft installation includes a tank, separate from the normal fuel system of the aircraft, to contain the methanol-water fluid. An electric-driven pump is used to feed the fluid, usually a mixture of 75% methanol and 25% water, under pressure to a methanol-water metering unit fitted to the engine. Some installations also include a pressure regulating valve when the electric pump is capable of a delivery pressure in excess of the normal operating pressure of the system.

61. The functioning of the pump and, therefore, of the system is automatically controlled by means of inter-switching, either by contacts on the throttle quadrant or on the supercharger gear control switch, dependent upon the type of installation. This inter-switching ensures that the methanol-water fluid is not injected during normal running, and also that the high boost is not used without injection of methanol-water.

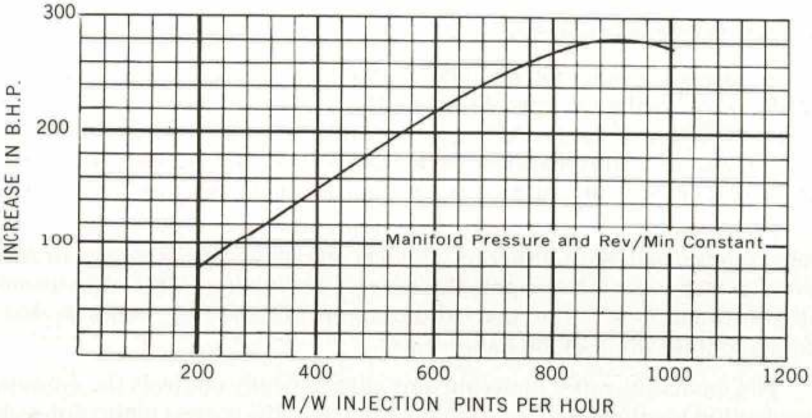
62. The methanol-water metering unit automatically controls the amount of fluid injected into the induction manifold and is rig calibrated to give the correct methanol-water flow rate. Non-leak devices are incorporated in the injection units to prevent fluid being drawn into the induction manifold when the injection system is inoperative.



Graph showing effect of water injection



Graph,fuel consumption/rate of injection



Graph,B.H.P./ rate of injection

Fig 1.4.10 Effects of water injection

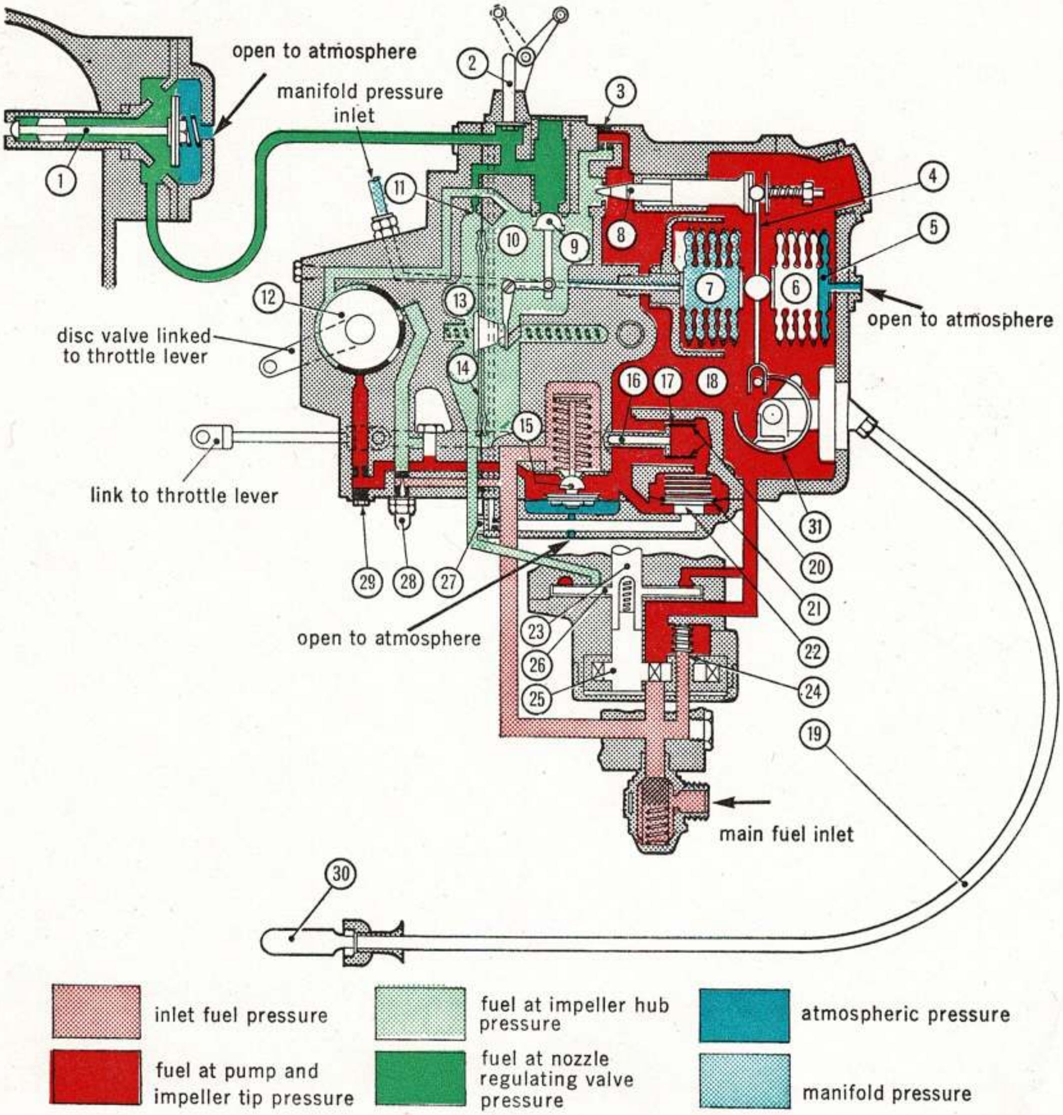
Safety Precautions when Handling Methanol-water

63. Make certain that no additional combustible liquid is added to the mixture. If contamination is suspected for any reason, then the system should be completely drained and flushed through. Other precautions to be taken are:

a. Make sure you do not inhale the vapour.

b. Wear rubber gloves when handling the fluid.

c. Methanol is corrosive—make sure there are no leaks in the system and that the mixture is not spilt.



1 FUEL DISCHARGE VALVE
2 FUEL CUT-OFF VALVE
3 TUNING JET
4 METERING NEEDLE OPERATING LEVER
5 EXHAUST BACK PRESSURE CAPSULE
6 EXHAUSTED CAPSULE
7 MANIFOLD PRESSURE CAPSULE
8 METERING NEEDLE VALVE
9 PRESSURE REGULATING VALVE
10 FUEL COMPARTMENT DELIVERY SIDE OF METERING NEEDLE
11 BLEED HOLE
12 S.R. AND ENRICHMENT VALVE
13 FUEL COMPARTMENT-IMPELLER EYE PRESSURE
14 DIAPHRAGM
15 FUEL PUMP RELIEF VALVE
16 ACCELERATOR PUMP
17 FLAP VALVE
18 FUEL COMPARTMENT-IMPELLER TIP PRESSURE
19 CAPILLARY TUBE
20 CALCULATED LEAKAGE SPACE
21 ACCELERATOR PUMP DIAPHRAGM
22 ACCELERATOR PUMP VALVE
23 FUEL PUMP DRIVING SHAFT
24 AUTOMATIC PRIMING VALVE
25 FUEL PUMP
26 FUEL PUMP IMPELLER
27 ACCELERATOR PUMP JET
28 SLOW RUNNING JET
29 ENRICHMENT JET
30 THERMOMETER BULB
31 BOURDON TUBE

Fig 1.4.2 Fuel control unit

★ AL.12.19