

SECTION 5, CHAPTER 10

DPA FUEL INJECTION PUMP

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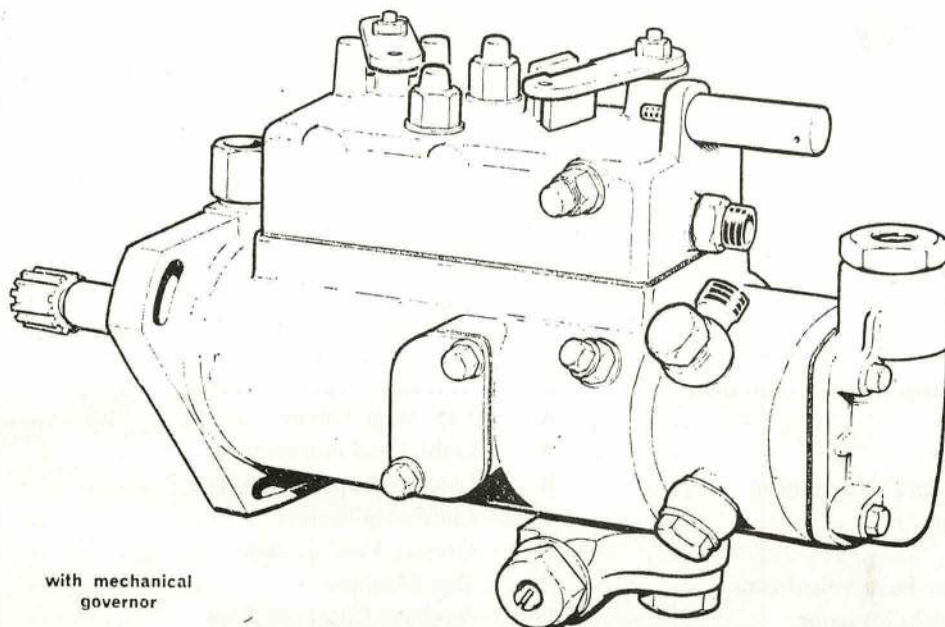
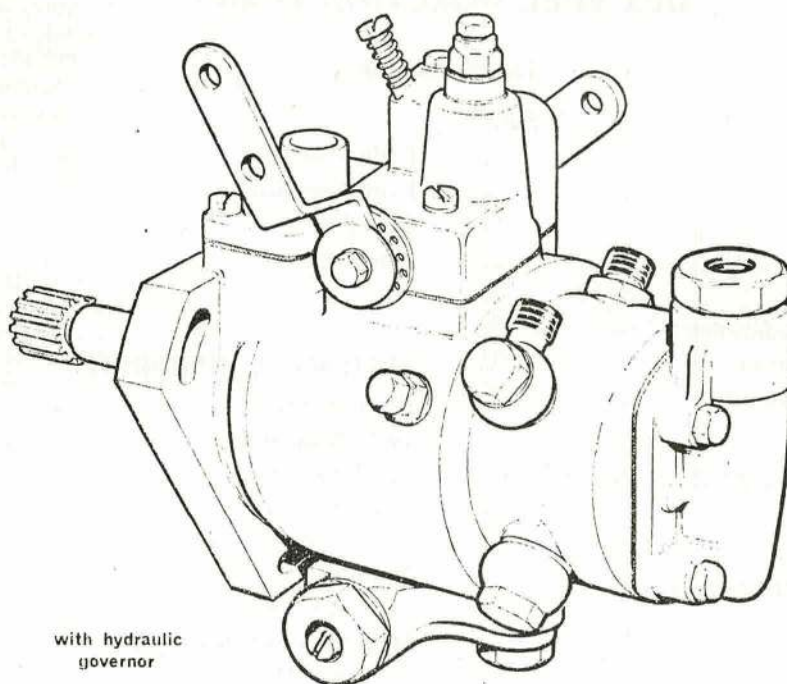


Fig. 1. TYPE DPA PUMPS

Introduction

1. The type DPA injection pump (Fig. 1) has several inherent advantages over the multi-element types which it was designed to supersede. The design has been simplified and there are no ball or roller bearings, gears or highly stressed springs. Also, the number of parts and overall size of the pump remain the same irrespective of the number of engine cylinders it is required to serve. Further, it is lighter, accurate phasing and equality of fuel delivery to each cylinder is ensured, no separate internal lubricant is required, pressure of the fuel prevents ingress of foreign matter and the pump can be fitted at any angle on the engine.

2. The pump is flange mounted on the engine and is driven by a splined shaft. It is a self-contained oil-tight unit, and during operation the housing is completely filled with fuel oil under pressure. This ensures:

(a) Adequate lubrication.

(b) That air locks are prevented from forming.

(c) Prevention of the entry of foreign matter.

3. The use of a single pumping element ensures that a uniform amount of fuel is delivered to each of the engine cylinders. This deletes the need for special equipment and the man-hours involved for balancing the delivery from each of the high pressure delivery pipes necessary with all multi-element pumps.

4. In this pump a metered quantity of fuel is fed between a pair of plungers which, when pushed inwards, feed the fuel via the rotating distributor and ports in the hydraulic head to each injector in the correct firing order. Thus as all injectors are fed from the same metering and pumping devices, the amount of fuel delivered to each injector is identical. The plungers are operated by cam lobes on a stationary internal cam ring having the same number of lobes as there are cylinders to be served.

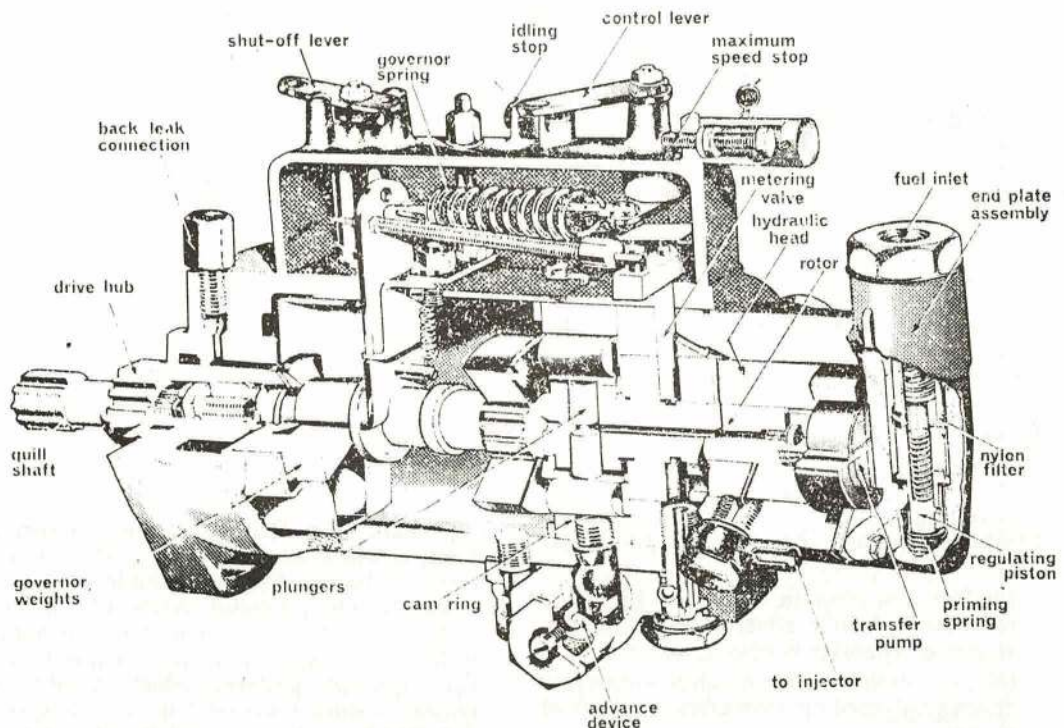


Fig. 2. PUMP—MECHANICALLY GOVERNED

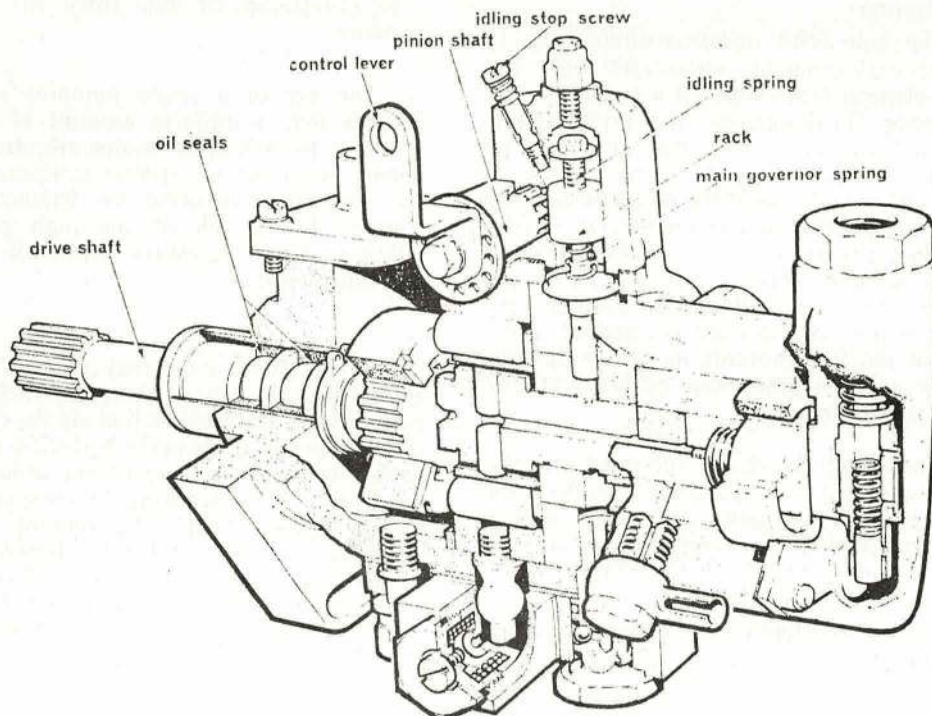


Fig. 3. PUMP—HYDRAULICALLY GOVERNED

5. A **governor**, either mechanical or hydraulic, is embodied in the pump to provide accurate control throughout the complete speed range of the engine and under all conditions of engine loading. An **advance mechanism** can also be fitted, if required, to vary the point of commencement of injection. Except where a manually operated **start retard** is incorporated, the advance device is fully automatic and requires no attention from the operator.

Description

6. The principal parts of the pump (Figs. 2 and 3) whether fitted with a mechanical or a hydraulic governor are the same. The most obvious differences between the two types are:

- (a) The reduction in length of the body with the hydraulic governor since the fly-weight mechanism is eliminated.
- (b) The simplified drive which eliminates the driving hub used on mechanically governed pumps.
- (c) The use of a sliding piston type metering valve on hydraulically governed pumps instead of the slotted semi-rotary type.

7. The main features can be seen in the cut-away illustrations (Figs. 2 and 3). Note that there are three main rotating units namely, a central steel pumping and distributing **rotor** which is driven by splines from a **drive shaft** and carries at its outer end a vane type fuel **transfer pump**. The mechanically governed pump distributor rotor drive shaft is splined at both ends and couples the rotor to a **drive hub** located in the end of the pump housing, whilst the hydraulically governed distributor rotor is driven by a single drive shaft.

8. **Pumping and Distribution Rotor.** The rotor has a pumping section and a distributing section which is a close rotating fit in a stationary steel cylindrical body known as the **hydraulic head**. These two units are machined to extremely fine limits and form a mated assembly. The pumping section of the rotor is larger in diameter than the distributing section and has a transverse bore that houses two opposed **plungers** which operate in unison. Inward movement of the plungers is obtained from the internal **lobes** of a stationary **cam ring** via **rollers** and **shoes** which slide in guide slots in the rotor. The lobes of the cam ring are equally spaced and, as mentioned

previously, are equal to the number of engine cylinders which the pump is designed to serve.

9. The distributing section of the rotor has a central axial passage that connects the space between the plungers with ports drilled radially in the rotor at two levels to provide for fuel inlet and delivery. The single port nearer the outer end of the rotor is the **distributing part** which, as the rotor turns, aligns successively with a number of **outlet ports**—equal to the number of engine cylinders—in the hydraulic head, from which the injectors are fed via external high pressure pipes.

10. A similar number of inlet ports in the rotor align successively with the single **metering port** in the hydraulic head for the admittance of fuel under the control of the governor.

11. An internally splined drive plate, with a master locating spline, is secured to the lower end of the rotor so that the splines mesh with the drive shaft and drive the rotor. Two screws which secure the plate are not diametrically opposite, and this ensures that the plate, when fitted, is assembled in the correct position relative to the inlet and outlet ports. The circumference of the plate is scribed with timing marks.

12. **Transfer Pump.** The transfer pump rotor is screwed into the outer end of the pumping and distributing rotor. The thread may be either left or right-hand depending on the direction of rotation of the pump, that is normal working tending to tighten the pump rotor. The pump rotor also locates the main rotor endwise in the hydraulic head. The pair of sliding blades run in a liner that is located in the hydraulic head by a dowel in the pump end plate which engages with a slot in the periphery of the liner.

13. **Hydraulic Head.** This is secured in the housing by three screws which permit only one assembly position. When an automatic advance unit is fitted (Fig. 2) the large location screw is replaced by the head locating fitting which provides a passage for

fuel at transfer pressure to the advance piston chamber.

14. A passage at the base of the housing for the transfer pump liner allows fuel to pass to an annular groove on the pumping and distributing rotor, and thence to the chamber in which the **metering valve** is housed. An "O" seal in an annular groove prevents leakage from the pump housing, and another seal is fitted in the upper face of the head to make the joint between the hydraulic head and the end plate leakproof.

15. **End Plate.** The end plate (Fig. 4) serves as a cover for the transfer pump and is secured to the hydraulic head by four unequally spaced screws so that it can be fitted in only one position. Two marked dowel assembly positions ("A" and "C") are provided in the end plate face for pumps of anticlockwise and clockwise directions of rotation respectively, the direction of rotation being viewed from the drive end of the pump.

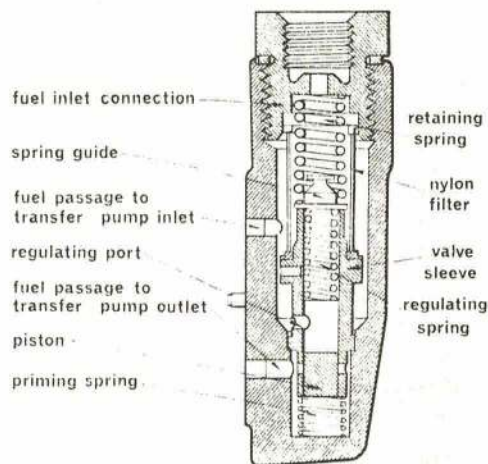


Fig. 4. END PLATE

16. The end plate houses the **regulating valve** assembly and a fine mesh nylon **filter**. The fuel inlet connection which locates and secures this assembly is mounted externally. The end plate illustrated (Fig. 4) is a recent type and is an aluminium die casting. Earlier end plates made of steel housed a similar regulating valve located on a centre line at right-angles to that of the fuel inlet connection, but functionally both valves are identical.

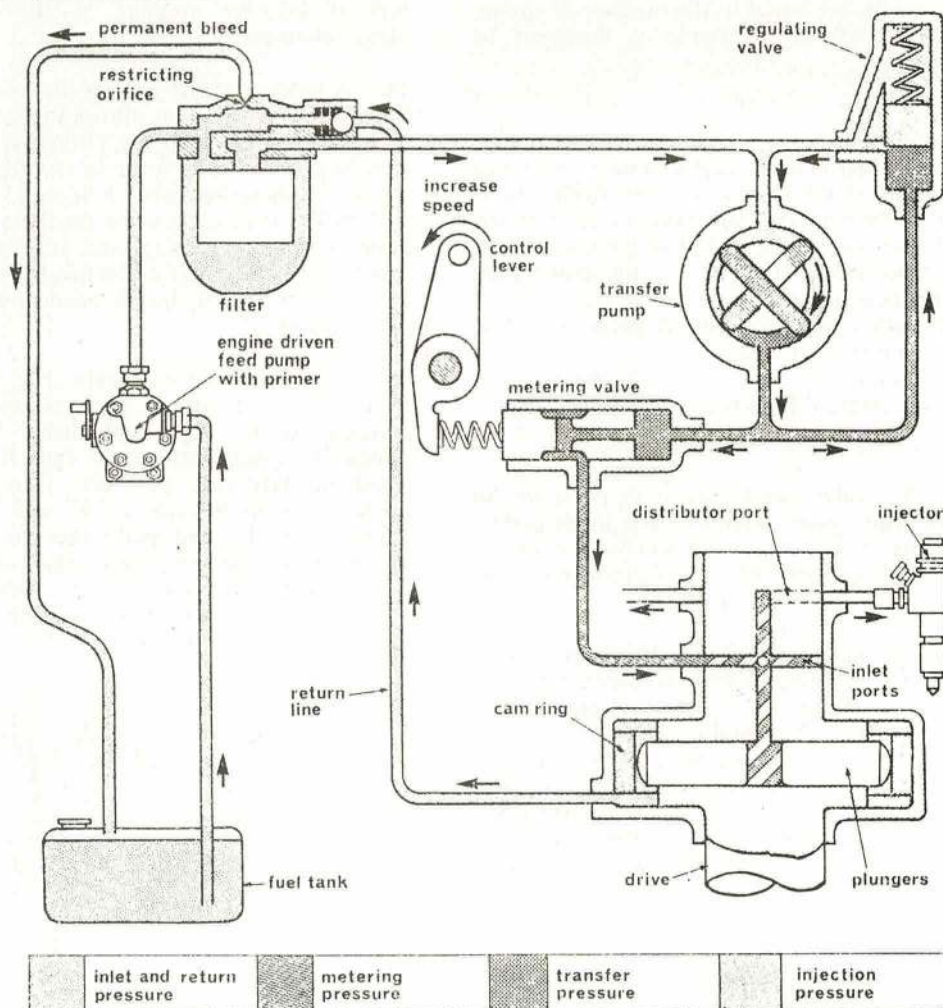


Fig. 5. FUEL FLOW

Operation

17. The flow of fuel is illustrated at Fig. 5. Fuel enters the pump at the end plate inlet at feed pressure and passes through a nylon filter to the transfer pump which raises the pressure to an intermediate level. Fuel from the pump passes down a passage in the hydraulic head and round an annular groove in the rotor to a radial bore in the head which connects with the metering port. The inlet to the metering port constitutes the metering orifice, and this is made variable, for control purposes, by the metering valve which is a close sliding fit in the radial bore.

18. The metering valve is operated by the control lever or the governor and regulates

the flow of fuel into the pumping section of the rotor. The volume of fuel passing into the pumping element is thus dependent upon the transfer pressure, the position of the metering valve and the time during which an inlet port in the rotor is aligned with the metering port in the hydraulic head.

19. **Pumping and Distribution.** The functions of pumping and distribution of the metered fuel are illustrated in Fig. 6. As the rotor turns, one of the inlet ports in the rotor aligns with the metering port in the hydraulic head and fuel at metered pressure flows into the rotor and forces the plungers apart. As rotation continues, the inlet port closes and the single distributor port aligns with one of the fuel outlets whilst both rollers contact the

opposing cam ring lobes and force the plungers towards each other. This is the injection stroke, during which the fuel trapped between the plungers is forced back at high pressure through the rotor and out to the injector.

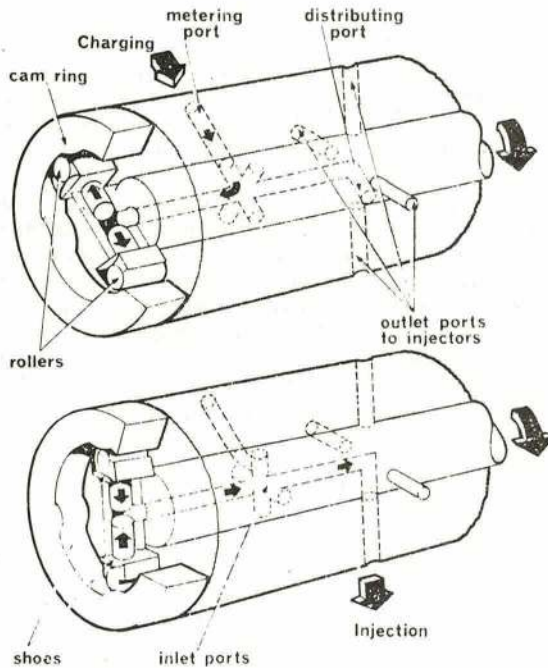


Fig. 6. PUMPING AND DISTRIBUTION

20. Fuel displacement ceases when the plungers reach the limit of inward travel imparted by the cam lobes, and shortly afterwards the distributor port closes and seals off the fuel pipe to the injector. The contour of the cam provides for relief of the pressure in the injector lines at the end of the injection cycle and thus prevents "dribble" at the nozzles. As the rotation continues the cycle is repeated, the pump discharging through each of the outlet connections in turn.

Regulating Valve

21. The regulating valve (Figs. 4, 7 and 8) is fitted for two purposes:

- It controls transfer pressure, maintaining a predetermined relationship between the pressure and the speed of rotation.
- It provides a way of by-passing the vanes of the transfer pump when the pump is stationary and it is required to prime the fuel passages in the hydraulic head.

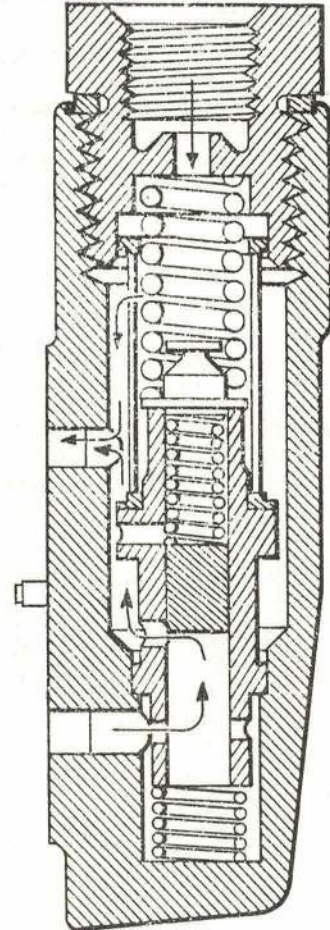


Fig. 7. REGULATING

22. **Regulating.** Fuel entering the end plate at feed pressure passes to the inlet side of the transfer pump through the nylon filter and the upper fuel passage. Transfer pressure is transmitted via the lower fuel passage to the underside of the regulating piston (Fig. 7) and tends to force the piston upwards. This force is opposed by the regulating spring pressure acting on the upper face of the piston. Any rise in transfer pressure, caused by increased engine speed, forces the piston upwards and compresses the regulating spring. Such movement of the piston progressively uncovers the regulating port and regulates transfer pressure by permitting a metered flow of fuel back to the inlet side of the transfer pump. The effective area of the regulating port is increased

with increased engine speed and reduced with decreased speed.

Note.—On some pumps the maximum movement of the piston is restricted by a screw in order to increase the rate at which transfer pressure rises. The screw, known as a **transfer pressure adjuster**, is set during manufacture to suit the particular application.

23. **Priming.** When priming a stationary pump, fuel entering the end plate cannot pass through the transfer pump and into the fuel passages in the hydraulic head in the normal way. Instead, fuel at priming pressure enters the valve sleeve (Fig. 8) and acts on the upper face of the regulating piston. The piston is forced to the lower end of the valve sleeve,

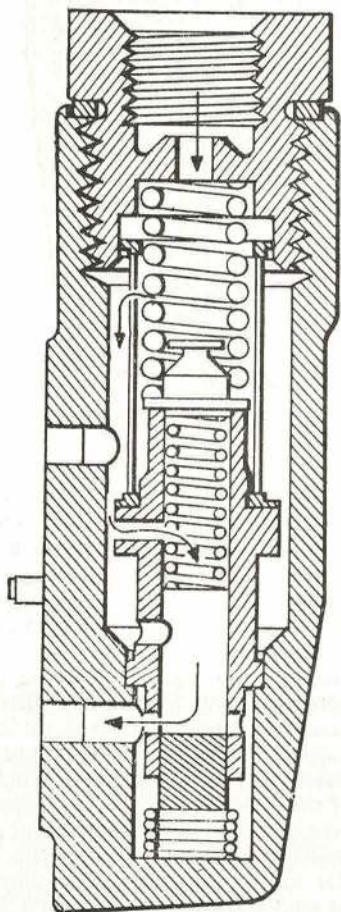


Fig. 8. PRIMING

compressing the priming spring and uncovering the priming ports. Fuel then passes through the priming ports and the lower fuel passage to the outlet side of the transfer pump, and thence into the fuel passages within the hydraulic head.

Fuel Metering

24. Apart from small losses (to be expected between working parts) which occur during the injection stroke, the total volume of fuel entering the element is pumped to the injector. The volume of the charge depends upon two main factors; the fuel pressure at the inlet port, and the time available for fuel to flow into the element whilst the inlet ports in the rotor and the hydraulic head are aligned. Metering is effected, therefore, by regulating the volume of fuel which enters the element at each charging stroke, and this is done accurately by control of the pressure at the inlet port. The various pressures in the system are shown in Fig. 5.

25. Fuel enters the injection pump at feed pressure and passes into the transfer pump which raises the pressure to a level known as transfer pressure. Transfer pressure is related to engine speed and rises as the speed of rotation increases. A predetermined relationship between transfer pressure and speed of rotation is maintained by the regulating valve. Fuel at transfer pressure passes through passages in the hydraulic head to the metering valve which controls the flow of fuel through the metering port. The effective area of the metering port is controlled by movement of the metering valve, which is connected by linkage to the accelerator pedal and the governor.

26. As fuel passes through the metering orifice a drop in pressure occurs which reduces the fuel pressure to a level known as metering pressure. The smaller the metering orifice the greater is the decrease in pressure and vice versa. This fuel at metering pressure then passes through an obliquely drilled passage in the hydraulic head.

27. At idling speed both transfer pressure and metering pressure are at their minimum values. Operating the accelerator moves the metering valve to a position where the effective area of the metering port is increased. This causes an increase in the metering pressure and consequent increase in the amount of fuel entering the pumping element at each

charging stroke. The increased supply of fuel enables the engine to accelerate to the speed corresponding to the position of the accelerator.

28. Releasing the accelerator reduces the effective area of the metering orifice and therefore the amount of fuel with consequent reduction of engine speed. When an engine is running at a fixed speed setting, the governor controls the position of the metering valve and maintains the selected speed within close limits by causing compensating changes of fuelling.

Maximum Fuel Adjustment

29. Since the amount of outward displacement of the plungers is governed by the amount of fuel permitted to enter the pumping element, a maximum fuel setting can be made by limiting the maximum outward travel of the plungers at the point where the desired fuelling is obtained. The cam rollers are carried in shoes which are in contact with the plungers (Fig. 9). The shoes slide in guides in the rotor and are retained at each end by adjusting plates. "Ears", integral with the roller shoes, project into eccentric slots in both adjusting plates, the ears being shaped to match the contour of the slots.

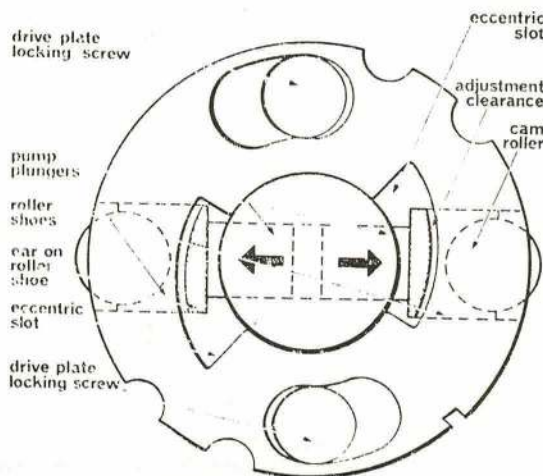


Fig. 9. MAXIMUM FUEL ADJUSTMENT

30. One adjusting plate is clamped between the drive plate and the end of the rotor. The drive plate locking screws pass through elongated holes in the adjusting plate, thus

allowing movement for adjustment when the screws are slackened. The plates are located one to the other by lugs formed on one of the plates.

31. The plungers reach their outward limit of travel when the ears on the roller shoes contact the curved sides of the slots in the adjusting plates. Fig. 9 shows the adjusting plates in the position which would provide the lowest possible maximum fuel setting. Since the slots in the adjusting plates are eccentric, maximum plunger travel will be increased if the adjusting plates are moved in a clockwise direction in relation to the rotor. The movement provided permits a wide range of maximum fuel settings.

Mechanical Governor

32. The mechanical governor (Fig. 10) is of the flyweight type, the weights being held in a carrier which is clamped between the driving hub and a step on the splined drive shaft. Weight assembly, drive shaft and hub thus rotate as a single unit. The weights are a sliding fit in the carrier pockets, and are so shaped that under the influence of centrifugal force they pivot about one edge.

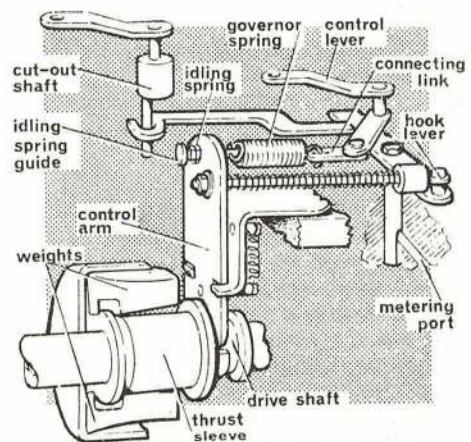


Fig. 10. MECHANICAL GOVERNOR

33. The weights are in engagement with the thrust sleeve which is a sliding fit on the drive shaft. The governor control arm pivots on the control bracket and is held in contact with the thrust sleeve by the tension of the governor spring. The tension of this spring acts in

opposition to centrifugal force, which means that it opposes outward movement of the weights. Spring tension can be varied by moving the control lever to which the spring is connected, tension being increased as the throttle control is moved towards the maximum speed setting.

34. The governor spring is not connected directly to the control arm but is coupled to the idling spring guide which passes through a hole in the arm and is loaded by the light idling spring. At speeds outside the idling range the tension applied to the governor spring is sufficient to compress the idling spring completely, thus rendering it ineffective. Within the idling speed range tension is removed from the governor spring and movement of the control arm by governor action is opposed by the idling spring only which gives sensitive control at low r.p.m.

35. The spring-loaded hook lever connects the upper end of the control arm with the lever which is secured to the metering valve. The cranked cut-out shaft is operated by the cut-out lever. Movement of the shaft is transmitted by the cut-out bar to the metering valve lever causing the valve to rotate to a position where the metering port is closed completely. The hook lever is spring-loaded to allow this movement without need for overcoming the resistance of the governor weights. When the cut-out lever is operated, the light hook lever spring is compressed and the end of the hook lever passes through the control arm.

36. **Operation.** Variations in the speed of the engine, and therefore of the pump, cause movement of the flyweights which is transmitted to the thrust sleeve and thence to the control arm and metering valve, thus admitting more or less fuel as required. An increase of engine speed resulting from decreased load causes the weights to move outwards, and such movement turns the metering valve towards the closed position which thus reduces engine speed. A reduction of engine speed with consequent inward movement of the weights causes an increase of fuelling which restores the selected engine speed.

37. Movement of the control lever tensions the governor spring to give the required resistance to movement of the control arm under the influence of the weights and thus obtain the required governed speed. An

increased throttle opening thus increases the spring tension and results in governor control at a higher r.p.m. and vice versa.

38. At any moment the engine can be shut down by means of the cut-out lever. The cut-out bar will then override the governor and rotate the metering valve to the closed position regardless of the position of the throttle lever.

39. Adjustment of the governor characteristics to suit a particular engine application is made at the time of assembly. Provision is made to connect the governor spring to any one of three positions provided on the connecting link (Fig. 10), and the idling spring can be assembled in any one of three positions on the control arm. The correct positions of assembly are quoted in the relevant Test Specification.

Hydraulic Governor

40. Unlike the mechanical governor which was contained within the pump housing, the component parts of the hydraulic governor are contained in a small casting secured to the upper face of the pump housing, the speed control lever and a cut-off lever being mounted externally.

41. The control lever (Fig. 11) is mounted on the pinion shaft and, within the governor housing, is the pinion with its engaged rack,

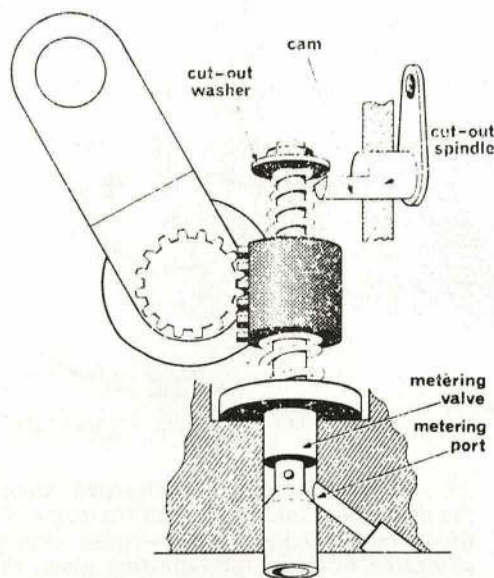


Fig. 11. HYDRAULIC GOVERNOR

the rack being free to slide on the stem of the metering valve. The rack is located between the governor spring and an idling spring. Fitted between the rack and a shoulder are damping washers. These slide in a cylindrical bore filled with fuel and acts as a dashpot to damp out any violent movement of the metering valve. The idling spring is located between the rack and a washer fitted at the top of the valve stem which is known as the cut-out washer. A screw which fits in the casing acts as an idling stop.

42. On some applications a device is fitted to prevent the engine from stalling when the engine control is closed to the idling position. Briefly, this consists of a spring loaded stop which prevents the metering valve from "snapping" closed. Operation of the cut-out control overcomes the loading of this spring and thus allows the metering valve to move to the fully closed position.

43. **Operation.** The governor is operated by fuel fed at transfer pressure from the annular groove surrounding the pump rotor. The fuel passes through the hollow metering valve, via transverse holes to an annular space around the valve. Thus there are two opposed forces acting upon the metering valve; spring pressure exerted by the governor spring and fuel transfer pressure acting on the underside of the valve. During normal operation the valve assumes a position where the two forces acting upon it are in equilibrium.

44. The metering valve is loaded by the governor spring, and this loading is manually adjusted by movement of the control lever. Movement of the metering valve varies and so controls the effective area of the metering port, thus controlling the metering pressure at the inlet port in the rotor and regulating the amount of fuel admitted to the pumping element at each charging stroke.

45. When the engine control is operated to give increased speed, the governor spring is compressed and the metering valve moves to the maximum fuel position. The increased fuelling causes speed to increase with a consequent increase in transfer pressure. When this pressure becomes greater than the spring pressure, the metering valve is moved back towards the idling position until the two forces are balanced. The engine will then run at a speed corresponding to the setting of the

speed control lever, and the selected speed will be maintained by governor action.

46. Any change in engine speed resulting from a change of loading is accompanied by a corresponding change of transfer pressure. This causes movement of the metering valve and brings about a compensating change of fuelling; increased fuelling when engine speed falls below the selected speed and decreased fuelling when the selected speed is exceeded.

47. Within the idling speed range the idling spring is compressed. The force it exerts on the metering valve is in the same direction as that exerted by transfer pressure. Thus, at idling speeds, these two forces oppose the reduced pressure exerted by the governor spring. This enables close governing to be maintained at low speeds where transfer pressure changes are relatively small.

48. Operation of the cut-out control causes the cam formed at the inner end of the cut-out spindle to contact the underside of the cut-out washer. This action lifts the metering valve to a position where the metering port is completely closed. The control can be operated at any engine speed, thus enabling the operator to cut-out the engine in an emergency.

49. **Reversible Fitting Governor.** This type of governor (Fig. 12) is a variation of the foregoing and may be found fitted to some of the pumps in service. The operating principle is the same as for the standard hydraulic governor except that movement of the control sleeve is obtained by using an eccentric formed

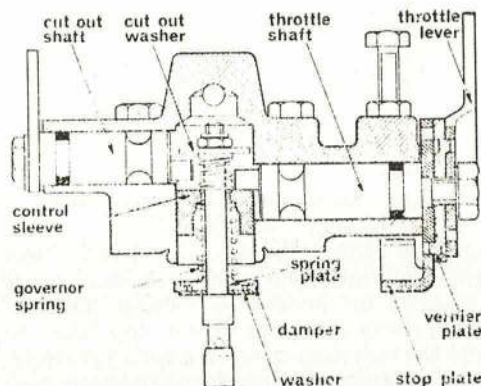


Fig. 12. REVERSIBLE FITTING GOVERNOR

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on the end of the throttle shaft. Rotation of the throttle shaft causes the eccentric to move the control sleeve against the governor spring, thus loading the metering valve. The cut-out mechanism operates in the same manner as that used in the standard governor.

CONTROL OF INJECTION TIMING

Automatic Advance

50. The mechanism illustrated (Fig. 13) progressively advances injection timing with increased engine speed. The piston is free to slide in its cylinder and any movement is transmitted by the ball-ended cam screw to the cam ring, thus causing the cam ring to turn within the pump housing. The springs tend to hold the piston and cam ring in the fully retarded position.

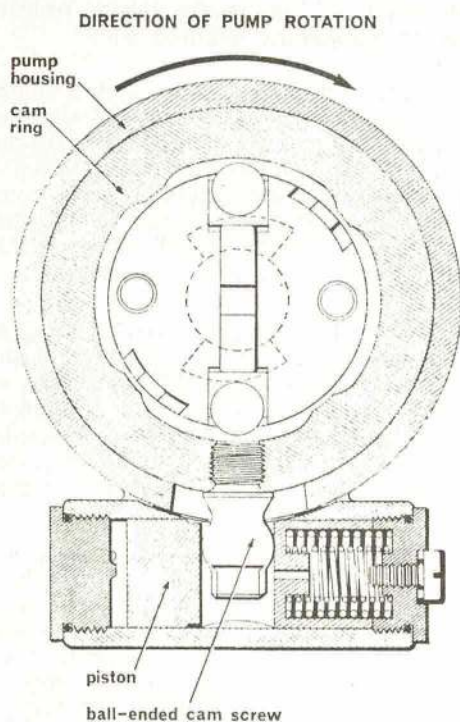


Fig. 13. AUTOMATIC SPEED ADVANCE

51. Fuel at transfer pressure enters through a passage in the screw by which the mechanism is secured to the pump housing. Transfer pressure acts upon the piston and tends to move the cam ring against the spring pressure. Transfer pressure increases progressively with increased engine speed, and this causes the piston to move along the cylinder and so to compress the springs and move the cam ring

towards the fully advanced position. When engine speed is decreased, transfer pressure also falls and spring pressure moves the piston and cam ring towards the retarded position.

52. The impact of the actuating rollers on the cam lobes at the moment injection commences tends to retard the cam ring, but such movement is prevented by a non-return valve located in the passage in the screw that secures the mechanism to the pump housing. Normal leakage between the piston and cylinder permits return to the retarded position when the engine speed decreases.

53. Any desired timing advance up to a maximum of 12 degrees (pump) is obtainable, and the engine speed at which this is attained can be varied by fitting stronger or weaker springs. The stronger the springs the higher will be the engine speed at which maximum timing advance is attained. Fine adjustment is made by the use of shims fitted between the springs and the spring cap.

54. **Automatic Start Retard.** It follows, that if a spring with a sufficiently low rate is fitted then full advance can be obtained at idling speed. This application is used in the automatic start retard device. When the engine is not running, transfer pressure is not available and the spring holds the cam ring in the fully retarded position. With the engine running at idling speed, transfer pressure overcomes the weak resistance of the spring and the injection timing is fully advanced throughout the engine speed range.

55. **Manual Start Retard.** This device embodies a remote controlled manual lock to hold the cam ring in the retarded position as an aid to starting the engine. It is designed so that movement of a lever holds the non-return valve on its seating and thus prevents transfer pressure from moving the piston. A screw type version of this device is also in use, the non-return valve being held in the closed position by means of a T-handled screw. Both devices are released manually when the engine has started.

56. **Automatic Start Retard with Speed Advance.** This is a two stage device (Fig. 14) which uses one spring to operate the start retard and heavier double springs for the speed advance. The device controls the injection timing in the following manner.

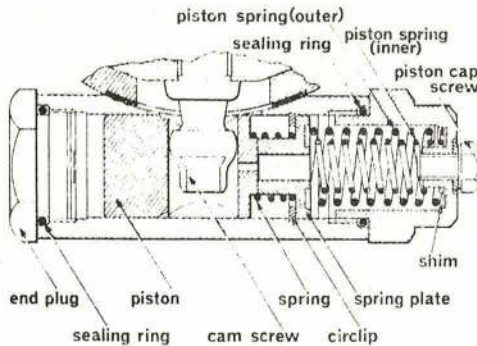


Fig. 14. TWO STAGE DEVICE

57. **Operation.** With the pump stationary the cam ring is held in the fully retarded position by the light pressure of the retard spring. When the engine is started and reaches idling speed, transfer pressure moves the cam ring to the correct timing position against the weak resistance of the retard spring. Increase of speed with the consequent increase of transfer pressure moves the piston further into the advanced position and, since the retard spring is now fully compressed, pressure is applied to the two piston springs. These springs have a higher rate than the retard spring and consequently they offer greater resistance and so allow a progressive advance of injection timing closely allied to the speed curve of the engine.

58. **Manual Start Retard with Speed Advance.** This is similar to the automatic device except that it incorporates a manual lock to hold the injection timing in the retarded position to aid starting. The lock is released manually when the engine is at idling speed and the speed advance automatically advances the timing progressively with an increase in engine speed.

Light Load Advance

59. **Mechanically Governed Pumps Only.** Under full load conditions, the maximum amount of fuel enters the pumping element and the plungers are forced fully outwards. As the rotor turns, the rollers contact the cam lobes on the cam ring at a point near the base of the cam. Under light loading conditions, less fuel enters the element with a consequent proportional reduction in the outward travel of the plungers and rollers. Contact, therefore, is now made at a point nearer the peak of the cam.

60. Since contact between the rollers and cams occurs progressively later in the cycle as fuelling is reduced, it follows that the timing of injection is progressively retarded. Misfiring, attributable to this inherent change in the timing, has been experienced on some engines when operating under light load conditions. Consequently, the modification illustrated in Fig. 15 has been devised for some models in order to overcome this problem.

61. The metering valve has two helical grooves of equal pitch, the upper one protruding beyond the hydraulic head and being open to fuel within the governor cover at drain pressure. The lower helix terminates at the lower end of the metering valve and is open to fuel at transfer pressure. The width of the land between the two helices is slightly less than the diameter of an additional port machined in the valve bore, situated opposite the metering port, and known as the **timing port**.

62. **Full Load.** With the metering valve in the full load position the upper helix is aligned with the timing port and drain pressure is applied to the piston in the conventional mechanism. This is not sufficient to overcome spring pressure and so the piston and cam ring remain in the retarded position.

63. **Light Load.** When the metering valve is moved to the low fuelling position under light load conditions, the lower helix is aligned with the timing port. Transfer pressure is applied to the piston so the piston and cam ring move to the fully advanced position. The pressure applied to the piston changes progressively from drain to transfer pressure as the metering valve is moved from the full fuel position towards the closed position.

64. Transfer pressure acting on the underside of the metering valve tends to force the valve upwards. The valve is located, endwise, by an abutment fitted in the governor control cover, and this can be adjusted to alter the relative positions of the helices on the valve and the timing port.

65. Since the low load advance is operated by transfer pressure, the engine speed at which it becomes effective is dependent on the strength of the particular spring that is fitted. The device can therefore be arranged so that low load advance is obtained between specific speeds or throughout the whole speed range.

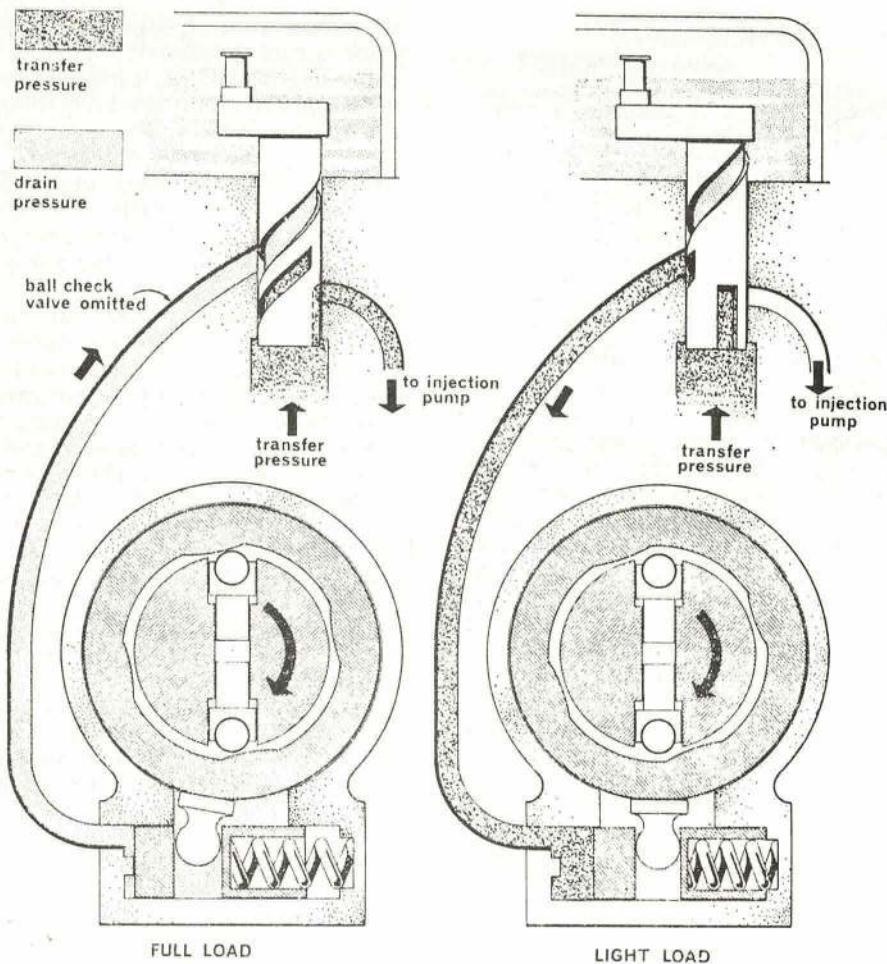


Fig. 15. LIGHT LOAD ADVANCE

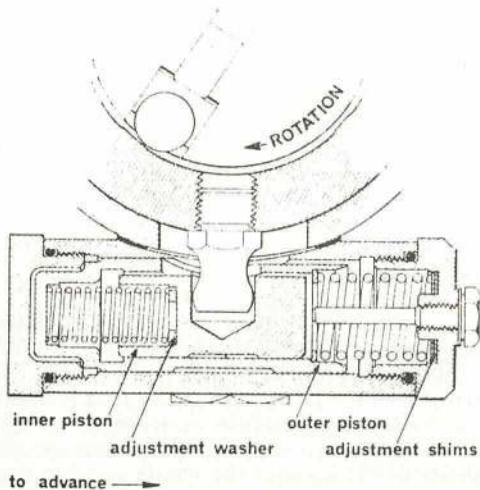


Fig. 16. LOAD AND SPEED ADVANCE

Combined Load/Speed Advance

66. Hydraulically Governed Pumps Only.

The mechanism illustrated in Fig. 16 is a combination of two of the mechanisms described previously. It provides:

- (a) Progressive injection timing advance as engine speed increases.
- (b) A compensating timing change which cancels the inherent retarding which results from the reduction of engine load.

67. This device comprises two pistons working one within the other in a standard advance device housing. The outer piston is sensitive to engine speed, being actuated by transfer pressure working in opposition to the force exerted by a spring. The inner piston is sensitive to load and is not subjected to transfer

pressure. It is spring-loaded in the direction of the advanced setting, and moves in response to changes in cam ring torque transmitted to it by the ball-ended lever. Cam ring torque increases with fuelling increase and vice versa. Movement of the inner piston is damped by dashpot action which is controlled by the dimensions of flats machined on the piston. The size of these flats and the working clearance of the inner piston are critical dimensions, since they affect the amount of load advance and also the injection characteristics.

68. With the engine idling unloaded, transfer pressure is at a minimum and the outer piston is held in the fully retarded position by spring pressure. Fuelling and cam ring torque are also at a minimum and the inner piston is held in the advanced position by spring pressure.

69. When a load is applied to the engine, fuelling increases, and the corresponding rise in cam ring torque is transmitted to the inner piston and moves it until it butts against a stop in the outer piston, the inner piston spring being compressed. This movement of the inner piston moves the cam ring towards the retarded position by an amount approximately equal to the inherent advance which occurs when fuelling is increased, therefore, injection timing is substantially unchanged.

70. If engine speed is increased, transfer pressure increases and both pistons move as a single unit to turn the cam ring to the fully advanced position. When engine loading is reduced at any point in the speed range, there is an immediate decrease in fuelling and a consequent reduction in cam ring torque. The inner piston then moves independently, and the advance imparted to the cam ring compensates for the inherent retardation which occurs when fuelling is reduced.

71. Certain pumps are fitted with a damper attachment to smooth out transfer pressure pulsations. This device is fitted with a diaphragm which absorbs the transfer pressure fluctuations and assists in stabilizing the auto advance device when testing or adjusting the pump.

APPLICATION

Fuel Systems

72. Typical fuel systems incorporating all the required features are illustrated in Figs. 17 and 18. Fuel oil may be fed to the injection pump by a lift pump or by gravity feed. In the latter case there must be a head of fuel of more than 1 ft.

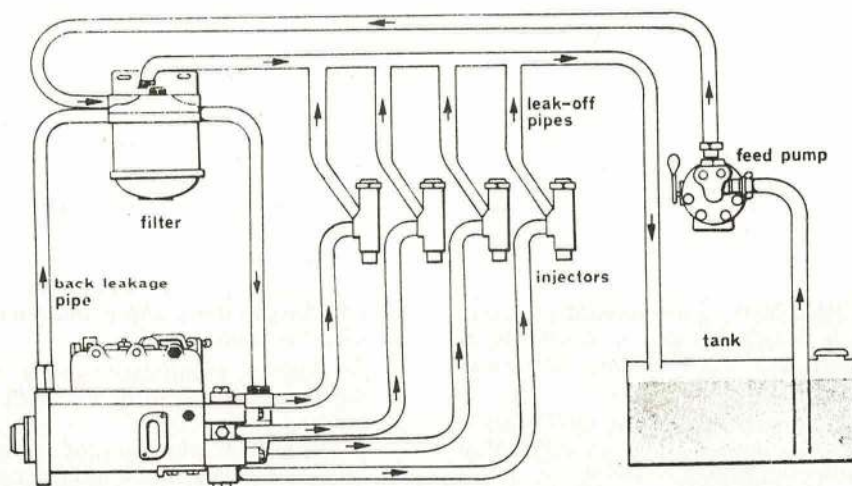


Fig. 17. LIFT PUMP SYSTEM

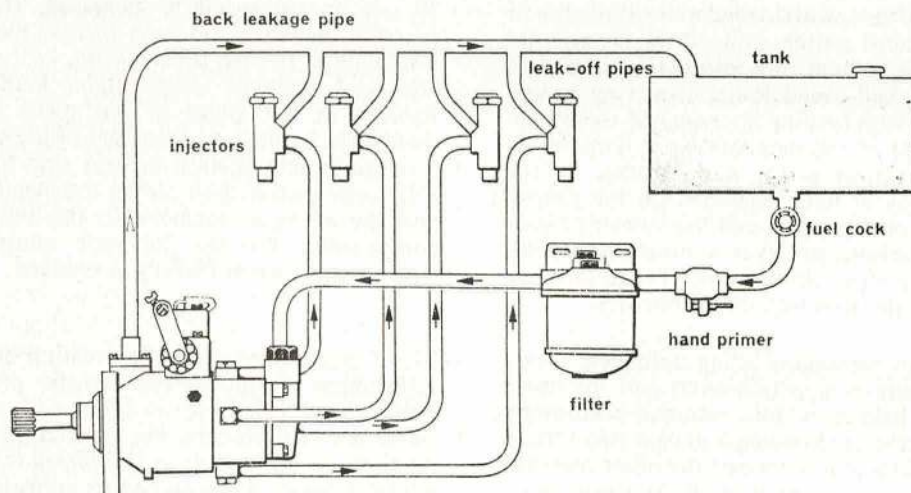


Fig. 18. GRAVITY FEED SYSTEM

Filtration

73. Since a large proportion of injection pump failures can be directly attributed to wear and damage caused by small particles of abrasive matter which have penetrated into the fine clearances between working parts, it will be realised that efficient filtration of the fuel oil is of the utmost importance.

74. Every precaution should be taken to prevent the ingress of any foreign matter into bulk storage tanks. It is also essential that the correct filter element is fitted, and periodic replacement as per the servicing schedule of the disposal type of paper element will ensure a high standard of efficiency.

Fitting and Timing

75. Both mechanically and hydraulically governed pumps are driven by a splined shaft provided with a master spline, which, with a corresponding fitting on the engine, ensures correct location for timing purposes.

76. The drive shaft on mechanically governed pumps is detachable and is referred to as a quill shaft, but the following differences may also be found:

- (a) On some applications the quill shaft is replaced by a special keyed drive hub that bolts on to the engine coupling.
- (b) Some early models have a quill shaft fitted with a small locking screw at one end. It is important that this screw is engaged in

the socket head of the drive hub securing screw before tightening the pump to the engine.

77. Some hydraulically governed pumps are fitted with a torsion bar to absorb backlash in the drive shaft. The bar runs through the centre of the drive shaft and is engaged between the end of the rotor and the pump drive coupling on the engine. It is made to twist during engagement of the pump to the engine.

78. Since the procedure for timing and fitting is not standard for all engines, reference must be made to the relevant publication before carrying out this work. In an emergency however, and if the timing marks are clearly marked on the engine and the pump mounting flange, most pumps can be fitted as follows:

- (a) Turn the pump drive shaft so that the master spline and splineway on the engine coupling are in alignment.
- (b) Enter the drive shaft into the engine coupling as the pump is mounted onto the securing studs.
- (c) Push the pump hard against the mounting face and secure lightly with the three holding nuts.
- (d) Rotate the pump on the retaining studs until the timing mark scribed on the edge of the pump mounting flange is accurately aligned with the timing mark on the engine.
- (e) Tighten the retaining nuts.

(f) Connect and tighten the back-leakage pipe.

(g) Connect and tighten the fuel pipe to the inlet connection on the pump end plate.

(h) Connect the cut-out lever on the pump to the control linkage and ensure that the lever has a full range of movement when the control is operated.

(j) Connect the throttle lever on the pump with the throttle control linkage and ensure that the lever has a full range of movement when the control is operated. Setting instructions for the control stops should be contained in the relevant publication.

Note.—Any attempt to start the engine must not be made until the pump has been filled and primed in accordance with the following instructions.

79. When a pump has been timed by the "emergency" method an early opportunity should be taken of checking the setting to the manufacturer's instructions.

Priming

80. The following sequence is applicable to the typical fuel systems shown in Fig. 17 and 18. When a particular fuel system varies from that shown in the illustrations, reference should be made to the relevant publication.

81. **Priming.** Priming is necessary on initial installation of the fuel injection system, after any subsequent removal, and if the system should be drained by running out of fuel. Before priming and venting, thoroughly clean the vent screws and the surrounding area so as to prevent the entrance of any foreign matter into the system. Proceed as follows and operate the fuel system priming lever whilst performing operations (a) and (b):

(a) Slacken the filter outlet (A) or the fuel pump inlet connection (B), whichever is the higher, and allow fuel to flow until free of air. Tighten connections.

Note.—Filters of the four boss type must also be vented at the plugged boss; this must be done irrespective of the height of the filter in the system.

(b) Slacken the vent valve fitted on one of the two hydraulic head locking screws (C), and the vent screw (D) on the governor housing. When the fuel flowing from the vents is quite free from air, tighten the

housing vent screw and then the governor vent screw.

(c) Slacken any two injector high pressure pipe unions at the injector end. Set the engine control to the fully open position and ensure that the cut-out control is in the "run" position. Turn the engine until the fuel flow is free from air; tighten the unions.

(d) Start the engine.

Note.—The priming procedure after changing a filter element consists of performing the operations detailed in sub-para (a).

Starting

82. When special starting aids are provided reference should be made to the relevant publication, otherwise proceed as follows:

(a) Ensure that the cut-out control is in the "RUN" position.

(b) Set the engine control in the full open position.

(c) Operate the starter button. When the engine is running evenly return the engine control to the idling position; the governor will then take over control.

(d) Where a manually operated start retard device has been used it must be released after starting, otherwise the pump will be retarded throughout the speed range of the engine.

Note.—If a new or reconditioned pump has been fitted, the idling stop must be adjusted and the maximum governed speed set according to the engine manufacturer's instructions.

Failure to Start

83. Starting difficulties are not always attributable to faulty injection equipment but may result from such mechanical faults as poor compression caused by cylinder wear, gummed-up rings, sticking or badly seated valves or from insufficient tappet clearance. When no starting aid is fitted, difficulty may also be experienced when attempting to start in extremely cold conditions. Check the fuel injection equipment as follows:

(a) Ensure that there is fuel in the tank and that the fuel cock is turned on. If the tank has been run dry, refill it and fill and prime the pump in accordance with the foregoing instructions.

- (b) Check the position of the cut-out control.
- (c) Inspect for leaks at the injector pipe connections and rectify as required.
- (d) Fill and vent the pump to remove all air from the system.
- (e) Inspect the filter element and replace with a new one if required. Prime the system after reassembling the filter.
- (f) Remove each injector in turn and after reconnecting the high pressure injector pipe with the nozzle directed away from the engine, turn the engine and ensure that fuel passed through the nozzle is correctly sprayed and atomised. Replace any faulty injectors.

Fault Rectification

84. The following are some of the causes of rough running, together with the appropriate remedies:

- (a) **Faulty Injectors.** Check and rectify as per para 83(f).
- (b) **Leaks.** Inspect all injection pipe unions for signs of leakage and tighten as necessary.
- (c) **Choked Filter.** Remove and replace the paper filter element and prime in accordance with the foregoing instructions.
- (d) **Air in Pump.** Slacken each injector pipe coupling at the injector end in turn while the engine is running. Re-tighten when fuel, free from air bubbles, leaks past the union threads. If this does not improve engine running, fill and prime the pump in accordance with the foregoing instructions.
- (e) **Water in Fuel.** When the presence of water in the fuel is suspected, the filter bowl should be drained daily until the amount of water so removed indicates that less frequent draining will be adequate to prevent water from entering the injection pump. If more than a teacupful of water is drained off, action must be taken to locate the source of ingress.

Servicing

85. Servicing will, of course, adhere to the servicing schedule, but apart from periodic replacement of the filter element and servicing of injector nozzles, a fuel system incorporating a DPA type of fuel injection pump requires a minimum of maintenance. If the necessary care is given to the cleanliness of fuel, both in

the fuel system and the bulk storage installation, the pump will give many thousands of hours of trouble-free service.

Inhibiting

86. When the equipment is to be out of use for long periods, for example, while in storage or in transit overseas, the pump and fuel injection system must be protected from corrosion in the following manner.

87. Each particular installation must be dealt with as the fuel layout demands. In general, the principle to be observed is that existing fuel should be drained as far as possible from the tank, filter and pipelines and the injectors. The whole system must then be refilled with a non-corrosive fuel, the pump being filled and primed, and the engine then operated for a period sufficient to ensure that the whole system has been inhibited. Detailed instructions should be given in the relevant publications which should be adhered to closely.

TESTING—ADJUSTMENT

Pressure Test

88. All pumps must be pressure tested after assembly and before being mounted on the test machine. This is done by connecting a supply of compressed air at a pressure of 20lb/sq. in. to the leak-off connection on the pump. Completely immerse the pump in a bath of clean fuel oil, turn on the air supply and check the pump for leaks. Any leak will be apparent from the bubbles of air emerging from the pump, and must be rectified before testing and setting the pump.

Test Machine

89. A typical machine for the testing of distributor type pumps is illustrated in Fig. 19. It incorporates the following basic features:

- (a) A mounting bracket to which the pump is secured during test, and a splined drive coupling through which the pump can be driven in either direction of rotation at all speeds specified in the range of test plans.
- (b) A set of high pressure pipes of equal length which couple the outlet connections on the pump to a matched set of injectors set at 175 atm. opening pressure.
- (c) A set of graduated measuring glasses arranged below the test injectors for measurement of the pump output, and a single

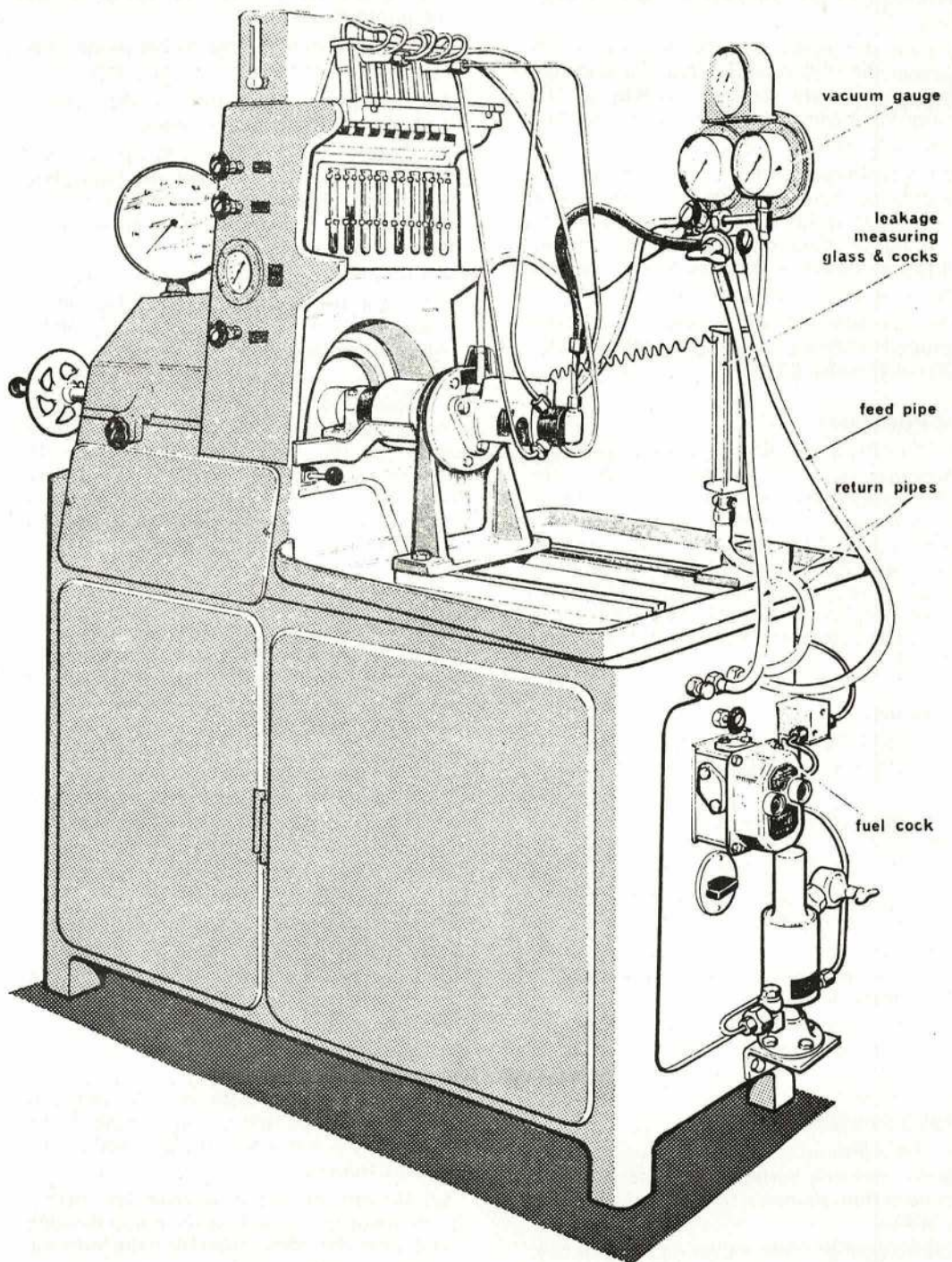


Fig. 19. TEST MACHINE

(AL 31, June 68)

measuring glass of larger capacity for measurement of the amount of back leakage fuel.

(d) An automatic trip mechanism which directs the fuel issuing from the injectors into the glasses during a period of 100 pumping cycles and then diverts the fuel into a drainage trough.

(e) A fuel system which ensures an adequate supply at constant pressure at the pump inlet. Delivery at the pump inlet should be a minimum flow of 1,000 ccs per minute. If this figure is not obtained it is permissible to use a pressure feed of 2lb per sq. in.

(f) One pressure gauge and one vacuum gauge for testing the output and efficiency of the transfer pump.

Test Procedure

90. Since pumps differ in output, governor characteristics and other respects according to the capacity and application of the engines on which they are intended for use, there is no standard test procedure which can be applied to all distributor type pumps. A separate test plan, quoting the despatch numbers of the range of pumps to which it may be applied, is published for each different model manufactured.

Precautions

91. The following precautions must be observed when testing DPA type fuel injection pumps:

(a) Ensure that the test machine is set to operate in the same direction of rotation as the pump to be tested.

(b) The pump must not be run for long periods at high speed with low fuel output.

(c) The pump must not be operated for long periods with the cut-out control in the closed position.

(d) The pump must be primed thoroughly before commencing the test and at other times when indicated in the test plan.

Priming Procedure

92. The general priming procedure is as follows, and any variation considered necessary on certain pumps is quoted in the relevant test plan:

(a) Slacken the vent valves on the governor control housing and the head locking screw.

(b) Connect the fuel feed pipe on the test

machine to the back leakage connection on the pump. Turn on the fuel supply and fill the pump housing.

(c) Fit the fuel feed pipe to the pump inlet and connect the back leakage pipe.

(d) Slacken the connections at the injector end of the high pressure pipes.

(e) Operate the pump at 100 r.p.m. Close the vent valves and tighten the high pressure pipe connections when it can be seen that the fuel issuing from each venting point is free from air bubbles.

(f) Examine all joints, pipe connections and seals for signs of leakage. The pump must be free from leaks at all times, whilst operating or when stationary

93. Testing and adjustment are effected by performing the operations in the order specified in the test plan. The purpose of each operation is indicated, and it will be noted that in addition to testing the overall efficiency of the pump certain other functions are checked independently.

Pump Output

94. Fuel delivery is checked by measuring the amount of fuel that passes through each injector during 200 pumping cycles at one or more speeds of rotation with the throttle lever in the fully open position.

95. The average delivery together with the overall tolerance and maximum permissible variation (spread) between the different injectors is quoted in the test plan.

Cut-out Control

96. The cut-out control is checked whilst running at a specified speed in the closed position, a maximum permissible fuel delivery being quoted.

Maximum Fuel Setting

97. Maximum fuel delivery is checked at a specified speed with both throttle and cut-out controls in the fully open position. If the fuel delivery is not within the specified limits, adjust as follows:

(a) Slacken the screws securing the inspection cover to the side of the pump housing and allow the fuel to drain from the housing.

(b) Remove the inspection cover.

(c) Slacken the two drive plate screws.

(d) Engage the special tool (7144/496) with the slot in the periphery of the adjusting plate.

(e) Adjust as required by tapping the knurled end of the tool.

(f) Tighten the drive plate screws to a torque value of 125lb in. using the adaptor (7144/482) and a standard torque wrench.

(g) Replace the inspection cover, refill the pump housing and check the maximum fuel delivery. Repeat the operations until the delivery is within the specified limits.

Note.—The adaptor (7144/482) is used in conjunction with an uncranked ring spanner when tightening the drive plate screws. The centre of the ring spanner must be 2.6 ins. from the centre of the adaptor. The torque and ring spanners must be in line whilst tightening the screws and care must be taken to prevent contact with the side of the aperture in the pump housing.

Governor Testing

98. With the pump operating at a speed greater than half the maximum permissible speed of the engine to which it will be fitted, adjust the maximum speed stop until the specified fuel delivery is obtained. This amount is considerably less than that for the maximum fuel setting.

99. Reduce the speed of rotation and the fuel delivery should increase to approximately the amount specified for maximum fuel delivery.

Note.—Final governor setting must be done on the engine in accordance with the engine manufacturer's instructions.

Transfer Pump

100. Transfer pump vacuum is checked whilst operating the pump at low speed, the two-way cock in the fuel feed pipe being set to the position which cuts off the fuel supply and connects the pump inlet to the vacuum gauge. A given depression must be attained in a specified time.

Note.—The pump may need to be reprimed after this test.

101. Transfer pressure is checked at one or more specified speeds. A special adaptor (7044/892) is screwed into the thread normally

occupied by one of the head locking screws so that a pipe can be fitted between the pump and the pressure gauge on the test machine. Thus, transfer pressure can be read directly from the gauge.

Speed Advance Device

102. The operation of this mechanism is indicated by use of a special tool (7044/896AE). To use this tool, proceed as follows:

(a) Remove the small screw from the piston spring cap on the advance device.

(b) Pass the threaded bush of the tool through the hole in the tool bracket.

(c) Insert the end of the plunger in the hole in the spring cap and then screw the bush into the spring cap screw hole. This will effectively clamp the bracket between the spring cap and a shoulder on the threaded bush (Fig. 20).

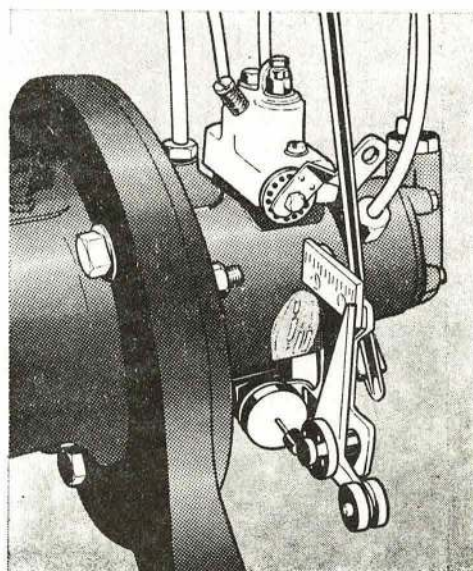


Fig. 20. ADVANCE CHECKING TOOL

(d) Adjust by moving the scale until the pointer indicates zero.

103. The specified advance must be obtained at a number of different speeds of rotation, thus checking the speed at which the device becomes effective and the speed at which full advance is obtained.

104. Adjustment is made by increasing or decreasing the thickness of the shims located between the piston spring and the spring cap. A single shim 0.5 m.m. thick is fitted during manufacture and must not be removed.

Note.—The pump must be primed after fitting this special tool.

Light Load Advance

105. Movement of this device is measured as for the aforementioned speed advance device, but since the former is sensitive to load it responds to changes of fuelling and therefore to changes in the position of the metering valve.

106. The test plan calls for a number of checks taken at different speeds with specified fuel deliveries obtained by positioning the throttle control. At each of these settings a specified advance should be obtained. Adjustment is made by:

(a) Moving the angular adjustment screw on the governor cover.

(b) Adjusting the thickness of shims fitted between the spring and the spring cap in the advance device.

Combined Load/Speed Advance

107. This series of tests carried out at different speeds and fuel deliveries checks the movement of the outer piston in response to changes of speed and the inner piston in

response to changes of load. Adjustment is by altering the thickness of shims fitted beneath the inner and outer piston springs.

Timing

108. Testing completed, fuel is drained from the pump housing by removing the inspection cover and the pump is removed from the test machine. The stirrup pipe (7144/262A) is connected to a specified outlet and to the outlet diametrically opposite. The relief valve (7144/155) is secured to the stirrup pipe and the complete tool is connected by a high pressure pipe to a nozzle testing outfit.

109. A pressure of 30 atm. applied by the pump forces the pump plungers apart as the pump is turned. Such movement brings the actuating rollers to a position where they strike the cam lobes, and resistance to further movement is encountered. With the pump held in this position, the timing ring is moved until the scribed line on the ring is aligned with a specified mark on the drive plate. The timing mark on the pump flange is made while the pump is held in the same position. The special tool (7144/112U) is set to the specified indexing figure and is then engaged with the splines on the pump drive shaft. The line is scribed by passing a scriber down the scribing guide on the tool.

Note.—When timing mechanically governed pumps it is imperative that the pump's own quill shaft is used to compensate for any possible wear on the splines.

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