Chapter 9

CHASSIS MOUNTED FUEL SYSTEM, TYPE C.M.F.S. SERIES

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Introduction

1. The C.M.F.S. combines in one unit all the engine fuel system components except the flow distributor, burners, and gallery pipes.

2. It is designed for use on two-spool turbo-jet engines, and the unit comprises two h.p. fuel pumps driven from the engine h.p. and l.p. compressors respectively, a full range flow control (f.r.f.c.), air/fuel ratio control (a.f.c.), electric pressure control (l.p.c.), double datum governor, and rate reset valves.

3. The types of C.M.F.S. in this series are similar in build and operation; the differences are shown in the table at the end of this chapter.

DESCRIPTION

Fuel pumps

4. The pumps are of the multi-piston, variable stroke type, fitted with a hydro-mechanical governor, and supply fuel through other controlling units of the C.M.F.S. to the burners.

5. The pump that is driven from the h.p. compressor incorporates the maximum speed governor; and the one driven from the l.p. compressor is fitted with the double-datum governor.

6. The pump body houses a rotor which is driven by a quill shaft and is supported at each end in carbon bearings. There are seven

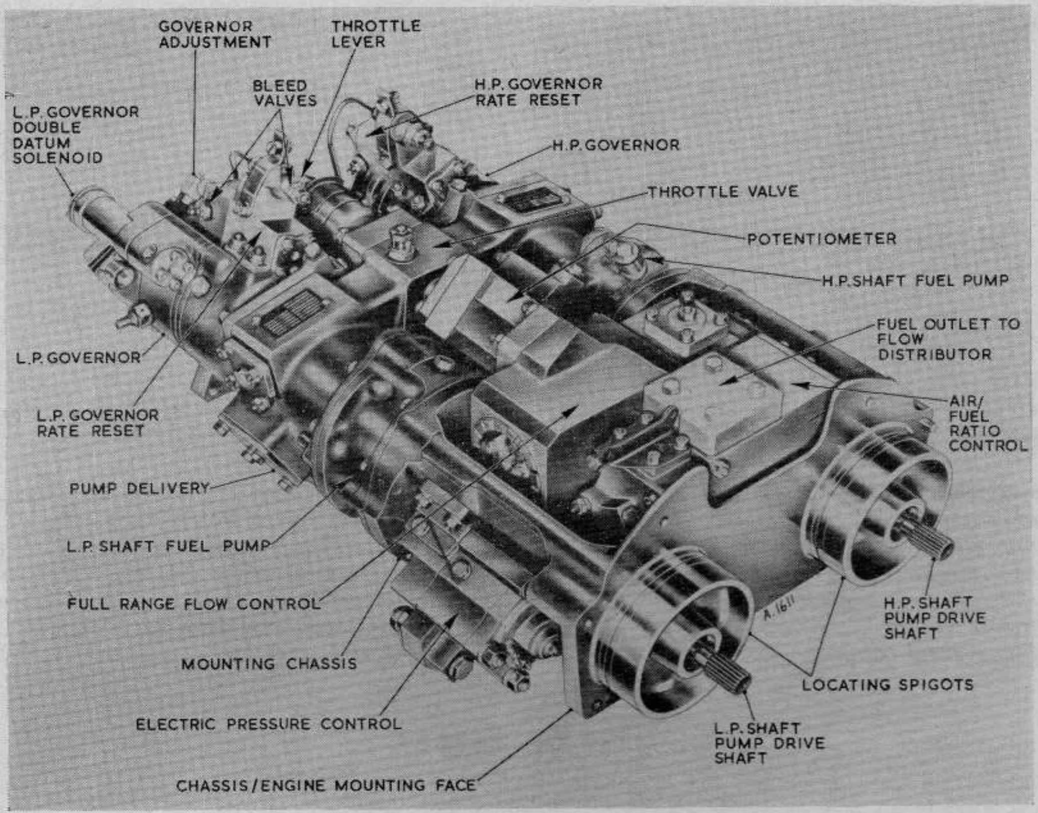

Fig. 1. Chassis mounted fuel system

inclined bores in the rotor accommodating spring-loaded hardened steel pistons, the ends of which protrude from their bores and are ball-shaped to suit the socketed slipper heads contacting a camplate. The camplate pivots in trunnions in its housing, its angle of inclination being varied by a servo piston and linkage, from zero to maximum piston stroke.

7. An auxiliary camplate drilled to take the slipper shanks, supports and maintains the slippers in position against the camplate face. It rotates with the rotor and is centrally mounted on a hemi-spherical thrust ball which is spring-loaded upon the stem of the rotor. The rotation of the rotor causes the pistons, which are located against the inclined camplate, to produce the pumping action.

8. The bores in the rotor are stepped and terminate in seven ports in the flat face of the rotor; this face contacts a hardened steel insert in which are formed kidney-shaped inlet and delivery ports. A pressure-tight seal is made by the rotor being pressed against the insert by the force exerted by the seven piston return springs and the fluid pressure acting upon the differential area formed by the stepped portion in the piston bores.

9. The fuel delivered from the pump passes to the f.r.f.c then to the a.f.c thence to the flow distributors and burners.

Pump stroke control mechanism

10. Control of the pump is effected by the servo control of a piston having an integral piston rod, operating in a cylinder. The piston rod is connected to the camplate by a link, thus movement of the piston will vary the angle of the camplate. High pressure fuel from the delivery side of the pump is supplied to the underside of the spring-loaded servo piston and, via a restricting orifice to the chamber above the piston.

11. Movement of the servo piston is determined by controlling orifices, which are responsive to measured conditions defining engine requirements. When the control orifices are closed, the pressures on each side of the servo piston are equal. The spring force assisted by the servo pressure upon the differential area above the servo piston moves the piston to incline the camplate to produce maximum pump piston stroke, and thereby maximum pump output. The opening of any servo control orifice allows fuel to escape from the chamber above the servo piston causing a pressure drop, and the piston moves against the spring loading to reduce the camplate angle hence pump piston stroke, and thus pump delivery. During steady running, the control orifices are just open, permitting a total leakage flow at the same rate as the flow through the restricting orifice, so that the servo piston remains stationary.

Hydro-mechanical governor (h.m.g.)

12. The h.m.g. consists of a cup-shaped rotor which is integral with its driving shaft. At its open end the rotor is sealed against the pressure in the surrounding chamber by a face plate and carbon face-seal; the opposite end, or base of the rotor, is drilled to permit chamber pressure to pass to a control orifice and to the lever counterbalance diaphragm.

13. A carrier bolted to the internal face of the rotor face plate retains the control orifice, the control cantilever hinge and counter balance diaphragm, and a balance weight which dynamically balances the control lever weight to ensure smooth running. The control cantilever leaf hinge secures one end of the lever, whilst the diaphragm is bolted at its centre to the centre of the lever and at its periphery to the bottom face of the carrier; a space beneath the diaphragm is enclosed by an orifice plate that permits fuel to pass from slots in the inner face of the rotor to the diaphragm face. This orifice plate permits the chamber pressure to be sensed fully by the diaphragm, but by restricting flow to and from the diaphragm damps out any tendency of the control lever to vibrate under adverse conditions.

14. The control cantilever lies across the rotor diameter and is arranged to swing in the line of the rotor axis. At its free end, the lever carries a weight on its upper side, the weight centre of gravity being offset from the plane of the leaf hinge; the lower surface of the lever immediately beneath the weight forms the valve which regulates the flow through the control orifice. Under operating conditions the weight centre of gravity tends to swing toward the plane of the leaf hinge, so that this end of the lever is moved towards the orifice to restrict the flow; the degree of movement permitted is restricted only by the influence of the counterbalancing diaphragm which, under chamber pressure, controlled by the spill through the orifice exerts an opposing force that is always proportional to the lever centrifugal loading and therefore, is a measurement of the rotor speed.

15. Fuel at pump delivery pressure is fed to the governor rotor chamber. The only outlet flow from this chamber is through the rotor control orifice and thence, through the rotor and face plate, to pump inlet. The pressure in the rotor chamber depends upon the balance between the pressure drop across each of the inlet and outlet orifices, and as the inlet orifice pressure drop is constant for a given pressure drop, any adjustment to the pressure drop across the rotor orifice will modify the chamber pressure.

16. In operation the control orifice pressure drop is regulated by the rotor cantilever valve. This is sensitive to speed under the influence of mechanical centrifugal loading on the lever weight. The chamber pressure opposes this centrifugal loading through the rotor lever diaphragm.

17. By this means the chamber pressure acting on the rotor diaphragm balances the centrifugal loading of the lever; the pressure is therefore a measurement of the centrifugal force and consequently is a measurement of rotor speed. As speed varies so the loading varies ; this unbalances the forces on the lever causing it to move and modify the orifice flow, which in return modifies the chamber pressure until the opposing forces on the lever are again equalised; the modified chamber pressures are a measurement of the altered speed.

18. The chamber pressure is a speed reference therefore, and this is applied to the maximum speed governor or any other control unit in the fuel system requiring a speed reference.

19. The maximum speed governor consists of a control orifice and half-ball valve arranged to be controlled by the pressure measuring the rotational speed of the hydromechanical rotor; this pressure is directed through drillings in the unit body to exert a force upon one side of a spring-loaded flexible diaphragm. A hardened tappet in the centre of the diaphragm is set to rest upon the end of a spring-loaded rocker lever mounted upon cross torsional hinges, and carrying at the other extremity a half-ball valve which is the sealing member of the control orifice.

20. As soon as the predetermined maximum speed is attained, the diaphragm is moved and the tappet will move the rocker lever to open the control orifice. Leakage of fuel at servo pressure now occurs from the chamber above the servo piston, and the piston moves to reduce the pump stroke, thus preventing any further increase in speed. The governor setting is adjusted by altering the loading of the governor control spring by means of the adjusting screw.

Full range flow control (f.r.f.c.)

21. The f.r.f.c. provides accurate matching of the engine characteristics up to the higher altitudes, and consists of the main throttle valve, idling control trimmer, potentiometer throttle valve, pressure drop control and altitude control.

Throttle valves

22. The main throttle valve is of the rotary type and operates in a sleeve formed with a series of graduated holes. By rotating the throttle valve, the holes can be progressively exposed or blanked to produce the required

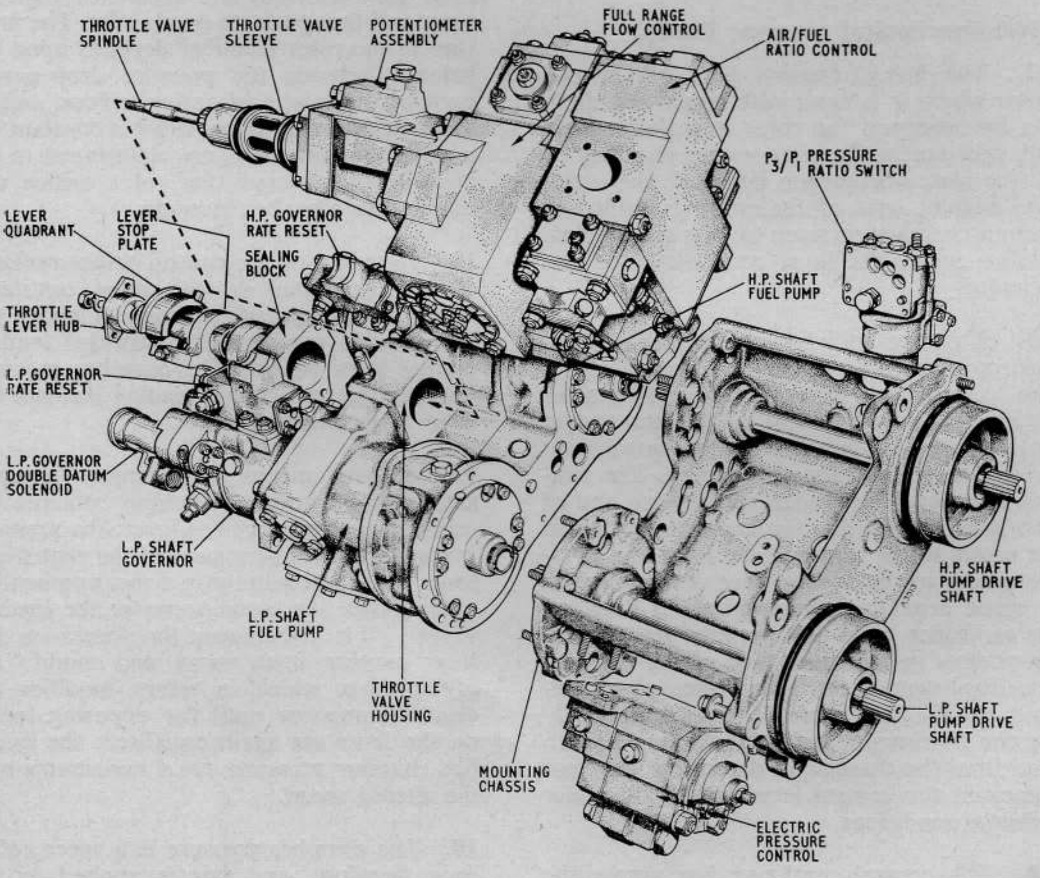

Fig. 2. C.M.F.S. Main sub-assemblies

degree of fuel control; and when the holes are completely blanked, the throttle valve serves as a shut-off cock.

23. The potentiometer throttle valve is also of the rotary type being linked with the main throttle valve and closes as the main throttle is opened. Its function, in combination with a fixed orifice across which the pressure drop control is connected, is to potentiometer the pressure signal to the p.d. control. This results in increased pressure drop across the f.r.f.c. as the main throttle is opened.

Idling control trimmer

24. This consists of a screw type trimmer situated in parallel with the main throttle valve and provides for the desired altitude idling condition by allowing an amount of fuel to by-pass the main throttle valve.

Pressure drop control (p.d.)

25. Control of the pump delivery is achieved by this control, which consists of a p.d. control piston which is spring-loaded and operates within a sleeve; the piston is connected mechanically through a push rod and rocker lever to a half-ball servo valve which controls an orifice in communication with the pump servo system. The control spring side of the piston senses metered fuel pressure from downstream of the altitude control plunger whilst the other side of the piston senses a higher pressure downstream of the potentiometer throttle. The difference between the pressures is maintained constant by the action of the mechanism, which will open the pump servo line to reduce the fuel flow if the pressure drop is exceeded and vice versa.

26. Being connected across the fixed orifice of the potentiometer circuit, the pressure drop control ensures a constant rate of flow through the potentiometer throttle. An orifice passes a constant flow of fuel to the lower pressure side of the p.d. piston, this flow having also passed through the potentiometer throttle. Variation of the potentiometer throttle area therefore, will incur a pressure drop additional to that across the p.d. mechanism; the total pressure drop is the controlling factor across the entire unit.

Altitude control

27. Pump delivery pressure also passes from the throttle valve to the underside of the altitude control metering plunger servo piston and an axial drilling in this carries the same pressure to the altitude idling needle.

28. Afer passing through the throttle valve, the throttle delivery flow and the by-pass bleed through the idling trimmer join together and pass to the altitude metering plunger; thence the flow passes through the metering orifice.

29. This throttle delivery flow is controlled initially by the throttle valve to a datum set by the pilot according to his requirements. The flow is modified by the metering plunger in response to ambient pressure, or altitude conditions, presented to the control as nacelle pressure P_1. Regulation of flow through the metering orifice is achieved in the following manner.

30. The piston attached to the metering plunger forms part of a servo system, the servo flow for which is supplied through an orifice in the piston.

31. A servo chamber above the piston is in communication through a drilling with an orifice and servo valve; the degree of valve opening and therefore the balance of servo pressure on the piston is controlled by the balance of two forces acting on the control cantilever. These forces are (a) the combined force of a datum setting spring and the P_1 bellows, opposing a force (b) which represents, through the metering plunger control spring and push rod, the position of the metering plunger. In equilibrium therefore, a balance is achieved between plunger position and P_1 pressure. Any alteration in P_1 pressure is sensed by the bellows and this, through a striker pin, deflects the cantilever and modifies the spill through the servo valve which, in turn, causes an alteration in servo pressure. This destroys the pressure balance across the servo piston which moves until the balance is restored between the piston spring loading and the belows loading. As the piston moves so also will the plunger move, thus modifying the fuel flow area through the control, both from the main circuit and the idling flow circuit in accordance with the altered conditions. The resulting change of pressure drop across the f.r.f.c. will be sensed by the p.d. control which will then demand the appropriate change of output from the fuel pumps.

Air/fuel ratio control (a.f.r.)

32. It is essential to control very accurately the amount of fuel supplied to the engine during acceleration in order to avoid possible compressor surge, excessively high jet pipe temperature and rich mixture extinction due to overfuelling.

33. The a.f.c. must allow the engine to accelerate in the shortest possible time and it must also make it impossible to overfuel the engine and stall the compressor. To satisfy these two conflicting requirements at all altitudes and atmospheric conditions, it is necessary to limit the fuel supply to the engine by using functions which are in themselves independent of altitude and atmospheric variation. These are (a) the ratio of air to fuel in the combustion chambers and (b) the compression ratio P_3/P_1 of the compressor, where P_3 is compressor delivery pressure, and P_1 is intake or nacelle pressure.

34. The primary purpose of this control unit is to elevate the compressor delivery pressure P_3, by measuring the compression ratio, and to relate the value obtained to a variable orifice controlling fuel delivery flow to the burners. The mass flow of air through the compressor for all practical purposes, can be taken as being directly proportional to compressor delivery pressure P_3 so that a value of P_3 can be used to control the fuel flow. As it is not sufficient to make the fuel flow proportional to the air mass flow over the whole speed range in this application, the P_3 signal to the a.f.c bellows is subjected to the control of a pressure ratio switch. This switch enables the ratio of fuel to P_3 at certain corrected speeds to be altered by supplying only a fraction of P_3 pressure into the bellows chamber at the lower speed range.

35. The a.f.c. comprises a fuel metering plunger which slides in an orifice. The plunger is attached by a spring to a rocker lever which is pivoted adjacent to one end, this end being attached to a capsule subject to P_3 proportional or P_3 pressure, depending upon requirements. The spring force and the force due to P_3 proportional or P_3 pressure on the capsule are kept in equilibrium in the following manner. An extension of the rocker lever, beyond the spring, operates a kinetic type servo valve. Any out-of-balance condition causes the valve to vary the pressure on a servo piston attached to the metering plunger, causing this to alter the spring loading and restore equilibrium. The principle of the kinetic servo valve is to control the kinetic energy of a jet of high pressure fuel by partially interrupting the jet with a controlled knife type blade. The energy of the uninterrupted part of the jet is then recovered as a pressure and used to control the servo piston movement of the metering plunger.

36. During operation, as there is no force on the servo valve itself, the force due to P_3 on the capsule and that exerted by the spring must be in equilibrium, therefore the spring force and spring extension must be proportional to P_3. As also the movement of the lever is negligible, the position of the metering plunger attached to the spring is proportional to P_3, and by suitably forming the end of the plunger the flow area of the metering orifice is made proportional to P_3.

37. By taking the pressure drop across this metering orifice and imposing this on a spring-loaded diaphragm controlling the pump servo system, the fuel flow is also made proportional to P_3. The pressure drop and spring-loading must again be in equilibrium, any unbalance being corrected by the pump servo system.

Pressure ratio switch P_3/P_1

38. The pressure ratio switch consists of an evacuated capsule secured to the switch housing at one end, and attached to a bellows at the other. The bellows is open and carries, on the face at its inner end a pad which, due to the flexing of the bellows under pressure, can be made to control the flow of air from an orifice. The interior of the bellows is connected to P_1 pressure and air from the engine compressor is spilled into the bellows via two fixed orifices in series. A tapping between the two orifices leads to the a.f.c. bellows chamber. While the switch is open, the pressure sensed by the a.f.c. bellows will be only a proportion of compressor pressure (P_3) depending on the ratio of the two fixed orifices. When the switch is closed, the downstream fixed orifice becomes sealed and full P_3 is applied to the a.f.c. bellows.

39. The switch is operated through the medium of an air potentiometer. This again comprises two series orifices through which P_3 is spilled to P_1. A tapping between the two orifices conducts pressure to the space surrounding the bellows assembly. The effective area of the outside of the bellows is less than that of the inside and this determines the ratio of P_3 to P_1, at which the switch will operate.

Electric pressure control (l.p.c.)

40. Control of engine temperature is through the l.p.c. which is connected in parallel with the potentiometer throttle. This control has a solenoid-operated half-ball valve controlling an orifice in communication with throttle upstream pressure. When the maximum temperature is reached, the solenoid becomes energised and allows the half-ball to be lifted and additional fuel to be fed into the pressure drop circuit. The p.d. control sensing an excessive pressure drop moves to reduce output from the pump.

Double datum governor

41. Where desired the engine can be operated by control of a double datum governor, the reference pressure for which is supplied by governor pressure from the pump driven by the low pressure compressor.

42. This governor gives a choice from two governed speeds, one for maximum engine speed and the other for cruising speed. Selection is made by energising a solenoid to open a half-ball valve for cruising speed governing, or leaving the solenoid de-energised (half-ball closed) for maximum speed governing.

43. When the valve is closed, pump delivery pressure acts on either side of the balanced piston of the double datum valve, but is maintained against a stop in the top position by a spring on its underside.

44. The rod of the piston is also attached to a lever which is secured through a spring to a diaphragm. The diaphragm is subject to governor pressure and contacts a rocker lever having a half-ball valve at its end, to seal a passage which is in communication with the pump servo system.

45. When the piston is against its stop in the top position, an increased governor pressure (representing maximum engine speed) is required before the pump governs by exerting a pressure on the diaphragm to open the half-ball valve.

46. When the solenoid valve is opened, unbalance of the double datum servo valve piston occurs and the piston moves against spring pressure to rest on the bottom stop or cruising speed datum. The lever then moves to relieve the spring loading on the diaphragm, and the half-ball valve spills fuel at pump servo pressure until the new equilibrium position representing the lower datum pressure, is established.

Rate reset valves (r.r.v.)

47. This valve, which functions as the fuel pump h.m.g. feed orifice, is a variable orifice providing increasing flow with reduction in pump delivery pressure. This has the effect of progressively resetting the governor datum and thus preventing governor 'creep' which occurs as altitude increases.

48. The valve comprises a square section body with inlet and outlet ports incorporated in the mounting face. A bolted plate embodying a maximum flow stop screw with a positive locked adjustment is assembled to one end of the body, whilst the opposite end is fitted with an end cap. The interior of the body houses a cylindrical sleeve in which operates a spring-loaded piston with a metering plunger attached. The plunger operates in an orifice which is retained in the end of the sleeve. Drillings in the wall of the piston sleeve permit fuel to pass to the chamber below the metering plunger thence through the orifice to the governor.

49. Fuel enters through the inlet port and strainer and passes to the chamber on the underside of the metering plunger, where the pressure is sensed on the plunger; this opposes the spring force. At high pump pressures the metering plunger moves further into the orifice thus reducing the flow through the unit, whilst at low pump pressures the piston and plunger move, under the influence of the spring, to withdraw the plunger from the orifice thereby permitting a corresponding increase in flow. The result is that at sea level conditions, when pump pressures are high, the flow through the unit will be at a maximum, whilst as altitude is gained and pump pressure is being reduced by the action of the f.r.f.c., the flow through the rate reset valve will increase accordingly. This will modify the h.m.g. signal to compensate for the effect of variations in pump pressure due to altitude, thus enabling the governor to maintain its required characteristics over a wide range of altitude.

Flow distributors and burners

50. Refer to Sect. 11, Chap. 4 of this publication for the flow distributors, and to Sect. 7, Chap. 4 for the burners.

Installing and servicing

51. The chassis on which the fuel system components are mounted, is spigoted to the engine and secured with nuts, washers and set screws on the drive end of the unit, and with two nuts, bolts and washers through lugs on the governor housings. Further details are given in the engine Air Publication.

52. No servicing is required apart from checks on the security of fuel and electrical connections. Instructions for the adjustment of the governors are contained in the engine Air Publication.

53. For information on inhibiting the unit, refer to A.P.4471A.

TABLE 1

Types of Chassis Mounted Fuel Systems

Type	Remarks
C.M.F.S. 2/1B	Basic unit as described
C.M.F.S. 2/1C	As C.M.F.S. 2/1B with revised P_3/P_1 switch calibration
C.M.F.S. 100	As C.M.F.S. 2/1C with revised calibration to suit outboard engines
C.M.F.S. 101	As C.M.F.S. 2/1C with revised calibration to suit inboard engines

Printed for H.M. Stationery Office by Christchurch Times Ltd., Christchurch.
(5723) Wt.46198-4976 1250 4/65 375/—

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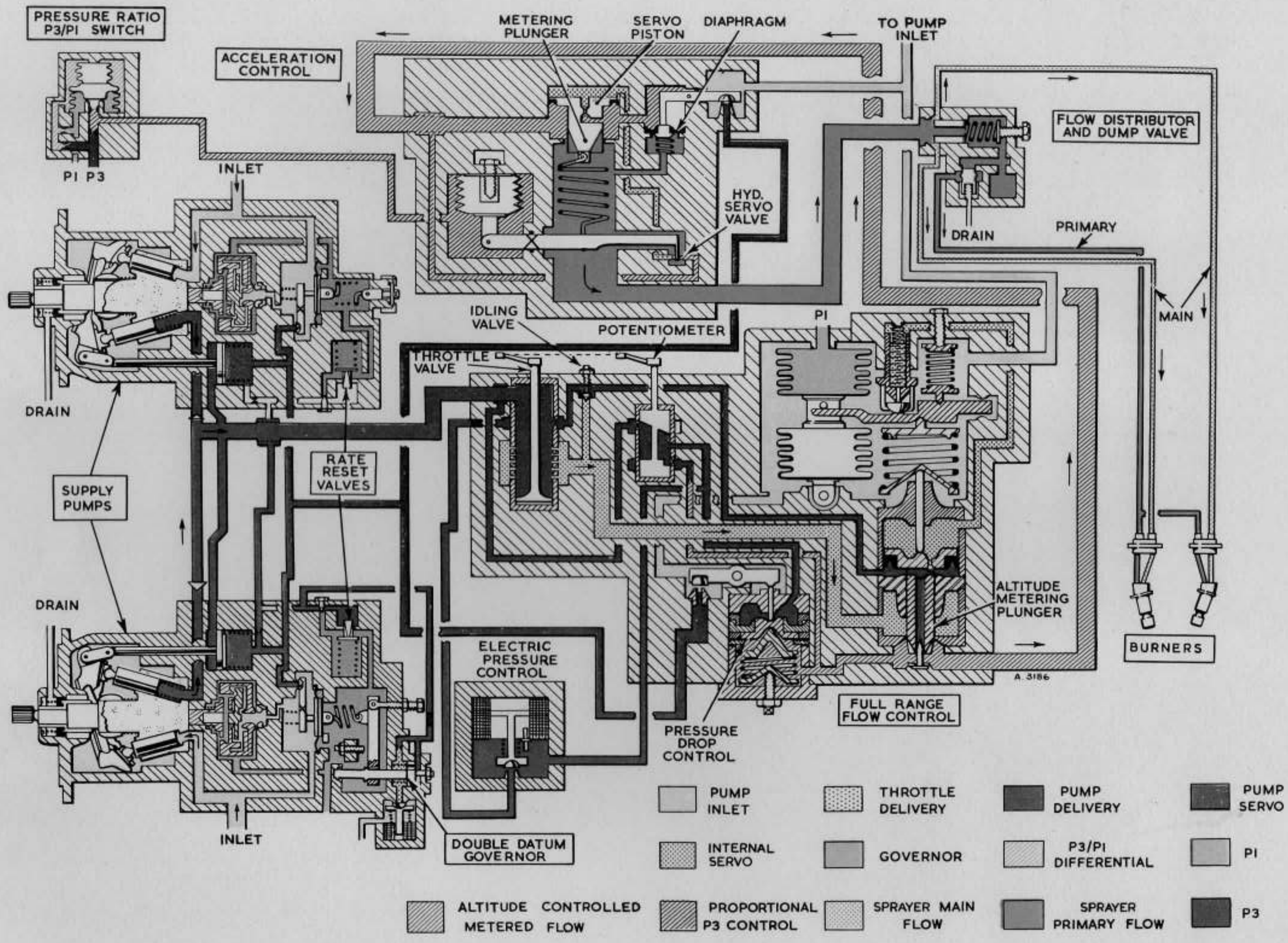

FIG. 3 FUNCTIONAL DIAGRAM