

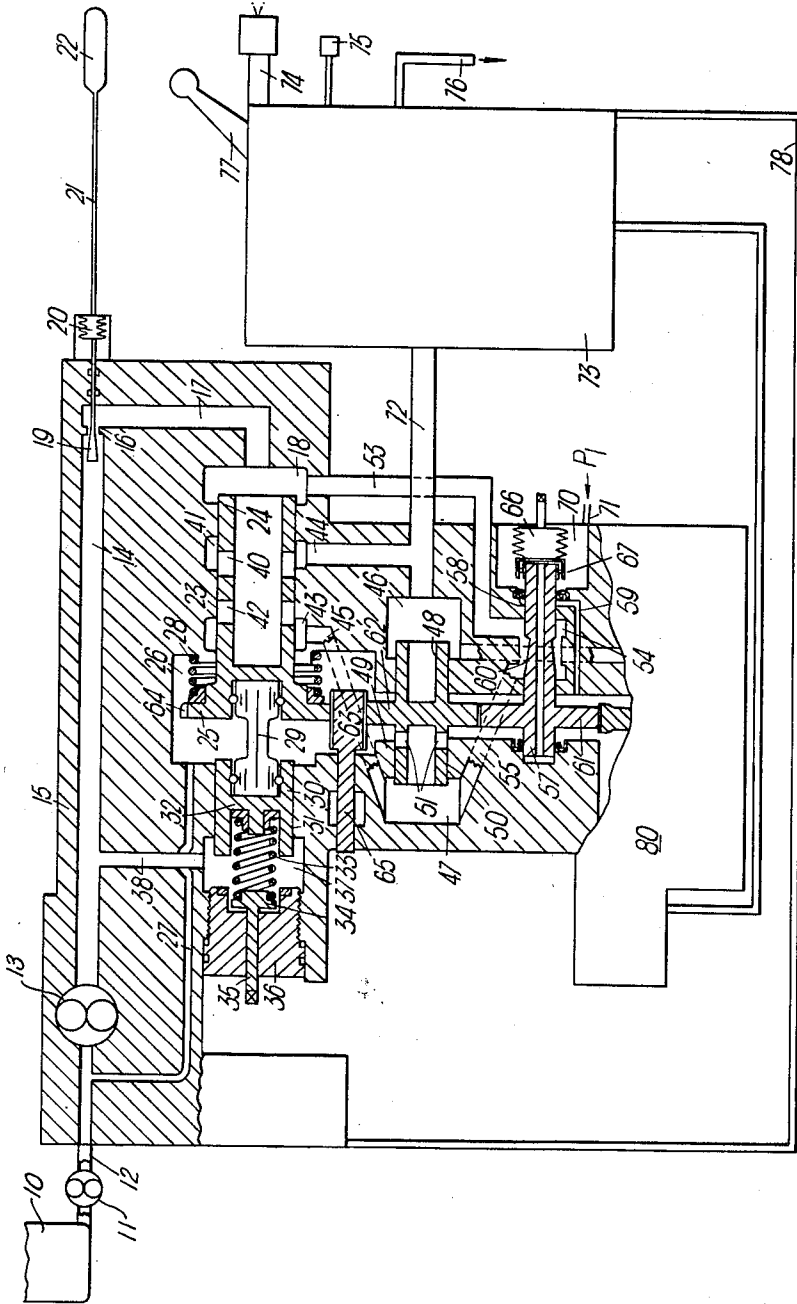
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GAS TURBINE ENGINE FUEL SYSTEM

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GAS TURBINE ENGINE FUEL SYSTEM

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This invention concerns gas turbine engine fuel systems.

According to the present invention, there is provided a gas turbine engine fuel system comprising a constant displacement pump, means for providing the low pressure side of the pump with fuel, a high pressure conduit communicating with the high pressure side of the pump, a fuel passage adapted to be connected to the engine burners so as to supply the latter with fuel, metering valve means whose position controls the flow of fuel from said high pressure conduit to said fuel passage, means for adjusting the position of the metering valve means, and hence the flow through the fuel passage, in dependence upon the value of one or more engine variables, and means for reducing or eliminating the effect on the flow through the fuel passage of variations in the pressure on the low pressure side of the pump.

In its preferred form, the invention comprises a gas turbine engine fuel system comprising a constant displacement pump, means for supplying the low pressure side of the pump with fuel at a given pressure, a high pressure conduit communicating with the high pressure side of the pump, a fuel passage adapted to be connected to the engine burners so as to supply the latter with fuel, a spill passage leading to the low pressure side of the pump, metering valve means whose position controls the relative quantities of fuel which may flow from said high pressure conduit to the fuel passage and spill passage respectively, means for adjusting the position of the metering valve means in dependence upon the value of one or more engine variables, and control means for maintaining substantially constant the quantity of fuel reaching the low pressure side of the pump from the spill passage in spite of increase or reduction of the said given pressure, whereby the flow of fuel through the fuel passage is substantially unaffected by variations in the value of the said given pressure.

The control means preferably comprises a variable restriction in the spill passage, and means for adjusting the variable restriction so that the pressure in the spill passage upstream thereof is always closely equal to the pressure in the fuel passage.

Thus the control means preferably comprises a spill pressure control valve whose position controls fuel pressure in the spill passage, oppositely facing pressure surfaces on said spill pressure control valve being respectively open to the pressures prevailing in said spill passage and fuel passage respectively immediately downstream of the said metering valve means.

Means may be provided for supplying fuel directly or indirectly, from the high pressure conduit to the spill passage in a quantity which increases upon decrease of a fluid pressure equal to, or functionally related to, the inlet pressure of the engine compressor.

Thus there may be provided a supply duct communicating with the high pressure conduit and with the spill passage on the upstream side of said spill pressure control valve, and a flow adjustment valve whose position controls flow through the supply duct, means being provided for adjusting the position of the flow adjustment valve in dependence upon the said fluid pressure.

The pump is preferably adapted to be driven by the en-

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gine, the high pressure conduit having a restriction therein the pressure drop across which is employed to position the said metering valve means.

Means may be provided for respectively increasing and reducing the effective size of the restriction in the high pressure conduit on increase and reduction respectively of a temperature equal to or functionally related to the inlet temperature of the engine compressor.

Preferably the metering valve means, the spill pressure control valve and the flow adjustment valve are axially movable by the pressures acting thereon, means being provided for effecting continuous rotation of all said valves.

The invention also comprises a gas turbine engine, e.g. a vertical lift engine, provided with a fuel system as set forth above. The term "vertical lift engine" as used in this specification is to be understood to mean an engine adapted to produce vertical lift forces on an aircraft independently of those generated aerodynamically in forward flight.

The invention is illustrated, merely by way of example, in the accompanying drawing which shows diagrammatically a gas turbine engine fuel system according to the present invention.

The terms "left" and "right," as used in the description below, are to be understood to refer to directions as seen in the drawing.

Referring to the drawing, a gas turbine engine fuel system, which is adapted for use on a vertical lift engine, comprises a fuel tank 10 having a booster pump or pumps 11 through which the fuel passes to a pipe 12. The pipe 12 leads to the low pressure or suction side of a constant displacement, engine driven, pump 13 which may, for example, be constituted by a gear pump.

A conduit 14 in a body 15 communicates with the high pressure or delivery side of the pump 13. The conduit 14 also communicates, by way of a restriction 16, with a conduit 17 leading to a chamber 18. It may be shown that the pressure drop across the restriction 16 is functionally related to the square of the speed of the engine driving the pump 13.

The effective area of the restriction 16 may be varied by a needle valve 19, the needle valve 19 being movable by a high expansion, fluid filled bellows 20. The bellows 20 is connected by a pipe 21 to a bulb 22 which is responsive to the inlet temperature T_1 of the gas turbine engine (or to a temperature functionally related thereto). The arrangement is such that the effective size of the restriction 16 is increased with increasing T_1 . The pressure drop across the restriction 16 is thus arranged to be proportional to N^2/T_1 , where N represents engine rotational speed.

Mounted for sliding and rotary motion within a bore 23 in the body 15 is a metering sleeve valve 24. The metering valve 24 has, at its left hand end, a flange 25. The flange 25 is disposed within a chamber 26 in the body 15, the chamber 26 communicating with the low pressure side of the pump 13 by way of a spill passage 27. The right hand face of the flange 25 is engaged by a stout spring 28 which bears against a wall of the chamber 26 and urges the metering valve 24 towards the left.

The metering valve 24 is drivingly connected by a quill shaft 29 to a sleeve 30 which is rotatably and slidably mounted within a bore 31 in the body 15. The sleeve 30 has a central web 32 against which bears one end of a light spring 33. The other end of the spring 33 bears against a spring plate 34 carried by a threaded stud 35.

The stud 35 is threaded within a block 36 and may be adjusted therein so as to vary the load on the spring 33. The spring 33 is disposed within a chamber 37 which is connected to the conduit 14 by way of a branch pipe 38.

The pressure surface at the left hand end of the sleeve 30 is equal in area to the pressure surface at the right hand end of the metering valve 24. The axial position of the metering valve 24 in the bore 23 thus depends on the pressure drop across the restriction 16 and hence depends on the value of N^2/T_1 , (or of N^2 if the temperature compensating needle valve 19 is not provided).

The metering valve 24 has a series of radial ports 40 therein which are adapted to communicate with an annular chamber 41 in the body 15. The metering valve 24 also has a series of radial ports 42 therein which are adapted to communicate with an annular chamber 43 in the body 15. The chambers 41, 43, communicate respectively with a fuel passage 44 and a spill passage 45. Axial movement of the metering valve 24 alters the effective size of the ports 40, 42 and hence adjusts the relative quantities of fuel which may be supplied to the passages 44, 45 from the conduit 17.

The passages 44, 45 lead respectively to chambers 46, 47. A sleeve valve 48, which constitutes a spill pressure control valve, is slidably and rotatably mounted within a bore 50 in the body 15. The spill pressure control valve 48 has its opposite ends extending into the chambers 46, 47 respectively.

The spill pressure control valve 48 has radial ports 51 therein which are adapted to communicate with the chamber 26 and hence with the low pressure side of the pump 13. The ports 51 also communicate, via the interior of the spill pressure control valve 48, with the chamber 47 and spill passage 45.

The body 15 has an internal wall 49 which overlaps the ports 51 to a greater or lesser extent depending upon the axial position of the spill pressure control valve 48. The wall 49 thus forms with the ports 51 a variable restriction.

The spill pressure control valve 48 is positioned solely by hydraulic forces and has at its opposite ends equal areas open to the pressures in the passages 44, 45. If, therefore, the pressures in the passages 44, 45 are unequal the spill pressure control valve 48 will move axially so as to increase or decrease, as the case may be, the effective size of the ports 51, whereby to increase or decrease flow through the chamber 26 and passage 27 to the low pressure side of the pump 13. Accordingly the spill pressure control valve 48 will always maintain the pressures in the passages 44, 45 equal to each other.

The chamber 18 communicates with a duct 53 leading to a chamber 54. The chamber 54 also communicates via a duct 55 with the chamber 47.

A flow adjustment valve 57, which is rotatably and slidably mounted within a bore 58 in the body 15, has a groove 60 whose depth increases axially towards the right. The valve 57 extends through the chamber 54, the groove 60 cooperating with the adjacent wall of the chamber 54 so that the amount of fuel which may flow from the duct 53 to the duct 55 depends upon the axial position of the flow adjustment valve 57.

Any fuel leaking past the flow adjustment valve 57 and flowing towards the right is returned to the chamber 26, by a bleed line 59.

The flow adjustment valve 57 is provided with a gear 61, which meshes with a gear 62 of the spill pressure control valve 48. The gear 62 is driven by a gear 63 which is also in mesh with gear teeth 64 which are provided on the flange 25. The gear 63 is driven from the engine by way of a shaft 65. Thus rotation is imparted to the valves 24, 48, 57 and such rotation diminishes the risk of their sticking.

A bellows 66 is connected to the outer race of a ball bearing 67 carried by the flow adjustment valve 57. The bellows 66 may thus impart axial movement to the valve 57 without being rotated thereby. The bellows 66 is disposed within a bellows chamber 70 which is supplied by way of a pipe 71 with air at the inlet pressure P_1 of the

compressor (not shown) of the engine, or at some pressure functionally related thereto.

The flow adjustment valve 57 thus effects increase and decrease of the quantity of fuel flowing through the duct 55 in dependence upon decrease and increase respectively in the value of the pressure P_1 . Fuel flowing through the duct 55 will, however, return via the chamber 47, ports 51, chamber 26 and passage 27 to the low pressure side of the pump 13. Hence the fuel supply to the fuel passage 44 will decrease with decreasing values of P_1 and thus with increasing altitude.

The flow adjustment valve 57 is an optional feature of the fuel system but its provision prevents excessive amounts of fuel being supplied to the engine, such as would cause surging thereof, when the engine is at high altitude, e.g. 20,000 feet.

A passage 72 communicates with the passage 44 and with a throttle and pressurising valve which is illustrated diagrammatically at 73. Fuel passing through the throttle and pressurising valve 73 may be supplied either to a main burner 74, or to a starting jet 75 and to a spill return passage 78 leading to the inlet of the pump 13, or to a dump passage 76 in dependence upon the setting of an engine control lever 77 which is adapted to adjust the position of the throttle valve.

A governor, shown diagrammatically at 80, may also be fitted to spill fuel into the chamber 26 and back to the inlet of the pump 13 through the spill passage 27 when the engine speed exceeds a selected value. The governor 80 may be connected hydraulically or mechanically to the throttle 73 to provide a variable setting of the maximum speed.

In operation, as engine speed increases, the speed of the pump 13 increases with a resultant increase in the pressure in the conduit 14. The pressure drop across the restriction 16 therefore rises and the metering valve 24 moves towards the right. This causes an increase in the fuel supply to the fuel passages 44, 72 and a reduction in the fuel supply to the spill passage 45 and so to the low pressure side of the pump 13.

Similarly a decrease in the value of T_1 will increase the pressure drop across the restriction 16 and will therefore also cause movement of the metering valve 24 towards the right so as to increase the fuel supply to the fuel passages 44, 72.

The pressure in the pipe 12 is liable, in operation, to fluctuate. Thus the tank 10 may, for example, supply both the forward propulsion and vertical lift engines of a vertical take-off aircraft and in this case fluctuation of the pressure in the pipe 12 may occur during the transition from vertical to forward flight or vice versa.

If, however, the pressure in the pipe 12, and hence on the low pressure side of the pump 13, were to fall, the pressure in the passage 27, and chamber 26, would fall correspondingly.

The pressure on the high pressure side of the pump 13 will not fall appreciably so that the spill flow through the ports 42, 51 will increase. The pressure in the chamber 47 will also fall by an amount less than the fall in pressure in the chamber 26, becoming less than the pressure in chamber 46. The spill pressure control valve 48 will therefore move towards the left so as to decrease the effective size of the ports 51 until the pressures in the chambers 46, 47 are equalised. The effect of this therefore is that the same amount of fuel is by-passed back to the pump 13 and the quantity of fuel supplied to the burners 74 is not therefore substantially affected by fluctuations in the pressure in the pipe 12.

If desired, the ports 40, 42 may be so arranged that, if an excessive engine speed is reached, flow through the ports 40 ceases.

If the flow adjustment valve 57 is fitted it is desirable that the sum of the areas of the ports 40, 42 exposed to the chambers 41, 43 respectively should be arranged to remain substantially constant when the metering valve

24 moves axially. If this is done it can be shown that a given position of the flow adjustment valve 57 can be arranged to give correct adjustment of the fuel flow to the engine for a given value of compressor intake pressure at all engine speeds.

For a vertical lift engine which does not have to operate up to high altitudes the flow adjustment valve 57, and the passages communicating therewith, may be omitted unless it is desired to start the lift engines at high altitudes in an emergency. In this case the sum of the said exposed areas of the ports 40, 42 need not remain constant. Also the needle valve 19 may be omitted and the restriction 16 used as a fixed restriction.

I claim:

1. A gas turbine engine fuel system comprising a constant displacement pump, means for supplying the low pressure side of the pump with fuel at a low pressure, a high pressure conduit communicating with the high pressure side of the pump, restrictor means for restricting flow through the high pressure conduit, a fuel passage adapted to be connected to the engine burners so as to supply the latter with fuel, a spill passage leading to the low pressure side of the pump, metering valve means whose position controls the relative quantities of fuel which may flow from said high pressure conduit to the fuel passage and spill passage respectively, said metering valve means having a first pressure surface, which is open to the high pressure conduit downstream of the restrictor means, and second pressure surfaces which are oppositely disposed with respect to the first pressure surface and which are respectively open to the high pressure conduit upstream of the restrictor means and to the spill passage, a spill pressure control valve whose position controls fuel pressure in the spill passage, oppositely facing pressure surfaces on said spill pressure control valve being respectively open to the pressures prevailing in said spill passage and fuel passage respectively immediately downstream of the said metering valve means, whereby the pressure in the spill passage upstream of the spill pressure control valve is always closely equal to the pressure in the fuel passage, a supply duct communicating with the high pressure conduit and with the spill passage upstream of the spill pressure control valve, and a flow adjustment valve means in said supply duct to control flow there-through in response to fluid pressure functionally related to the inlet pressure of the engine compressor.

2. A gas turbine engine fuel system comprising a constant displacement pump, means for supplying the low pressure side of the pump with fuel at a low pressure, a high pressure conduit communicating with the high pressure side of the pump, restrictor means for restricting flow through the high pressure conduit, a fuel passage adapted to be connected to the engine burners so as to supply the latter with fuel, a spill passage leading to the low pressure side of the pump, metering valve means whose position controls the relative quantities of fuel which may flow from said high pressure conduit to the fuel passage and spill passage respectively, said metering valve means having a first pressure surface, which is open to the high pressure conduit downstream of the restrictor means, and second pressure surfaces which are oppositely disposed with respect to the first pressure surface and which are respectively open to the high pressure conduit upstream of the restrictor means and to the spill passage, a spill pressure control valve whose position controls fuel pressure in the spill passage, oppositely facing pressure surfaces on said spill pressure control valve being respectively open to the pressures prevailing in said spill passage and fuel passage respectively immediately downstream of the said metering valve means, whereby the pressure in the spill passage upstream of the spill pressure control valve is always closely equal to

the pressure in the fuel passage, a supply duct communicating with the high pressure conduit and with the spill passage on the upstream side of said spill pressure control valve, a flow adjustment valve in said supply duct, whose position controls flow through the supply duct, and means for adjusting the position of the flow adjustment valve in dependence upon a fluid pressure functionally related to the inlet pressure of the engine compressor.

3. A gas turbine engine fuel system as claimed in claim 2, in which the metering valve means, the spill pressure control valve and the flow adjustment valve are axially movable by the pressures acting thereon, means being provided for effecting continuous rotation of all said valves.

4. In a gas turbine engine, a fuel system comprising a constant displacement pump, means for supplying the low pressure side of the pump with fuel at a low pressure, a high pressure conduit communicating with the high pressure side of the pump, restrictor means for restricting flow through the high pressure conduit, a fuel passage adapted to be connected to the engine burners so as to supply the latter with fuel, a spill passage leading to the low pressure side of the pump, metering valve means whose position controls the relative quantities of fuel which may flow from said high pressure conduit to the fuel passage and spill passage respectively, said metering valve means having a first pressure surface, which is open to the high pressure conduit downstream of the restrictor means, and second pressure surfaces which are oppositely disposed with respect to the first pressure surface and which are respectively open to the high pressure conduit upstream of the restrictor means and to the spill passage, means for respectively increasing and reducing the effective size of said restrictor means on increase and reduction respectively of a temperature functionally related to the inlet temperature of the engine compressor, and a spill pressure control valve whose position controls fuel pressure in the spill passage, oppositely facing equal pressure surfaces on said spill pressure control valve being respectively open to the pressures prevailing in said spill passage and fuel passage respectively immediately downstream of the said metering valve means, pressure imbalance between said pressure surfaces varying flow of spillage whereby the pressure in the spill passage upstream of the spill pressure control valve is always closely equal to the pressure in the fuel passage, a supply duct communicating with the high pressure conduit and with the spill passage on the upstream side of said spill pressure control valve, a flow adjustment valve in said supply duct, and means for adjusting the position of the flow adjustment valve in dependence upon a fluid pressure functionally related to the inlet pressure of the engine compressor.

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