United States Patent [19]

Turner

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[54] **METERED SUPPLY OF LIQUIDS**

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Related U.S. Application Data

[63] Continuation of Ser. No. 318,783, Dec. 27, 1972, abandoned.

[30] **Foreign Application Priority Data**

Jan. 6, 1972 United Kingdom 570/72

[52] **U.S. Cl.** **417/79;** 417/87; 417/184; 417/189

[51] **Int. Cl.²** **F04B 23/04;** F04F 5/48

[58] **Field of Search** 417/79, 80, 87, 184, 189, 417/197; 89/89; 239/533

[56] **References Cited**

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[57] **ABSTRACT**

In a liquid-supply system in which part of the delivery of a fixed-delivery pump is, as spill flow, returned to the pump inlet, the re-introduction is effected by a variable-geometry injector device to achieve, over a relatively wide range of spill ratios, effective utilisation of the spill-flow energy to raise the inlet pressure of the fixed-delivery pump. Conveniently this geometry adjustment is arranged to be utilised simultaneously for the adjustment of the spill ratio by injecting the spill flow in the form of a hollow converging cone formed between an inner cone wall surface of a valve housing and an outer cone surface of a head portion provided on a valve member which is slidable in the valve housing towards and away from the inner cone wall under the action of a signal pressure communicated via a line from a consumption control system to a chamber, in which it acts against a spring, on a diaphragm connected to the valve member.

10 Claims, 4 Drawing Figures

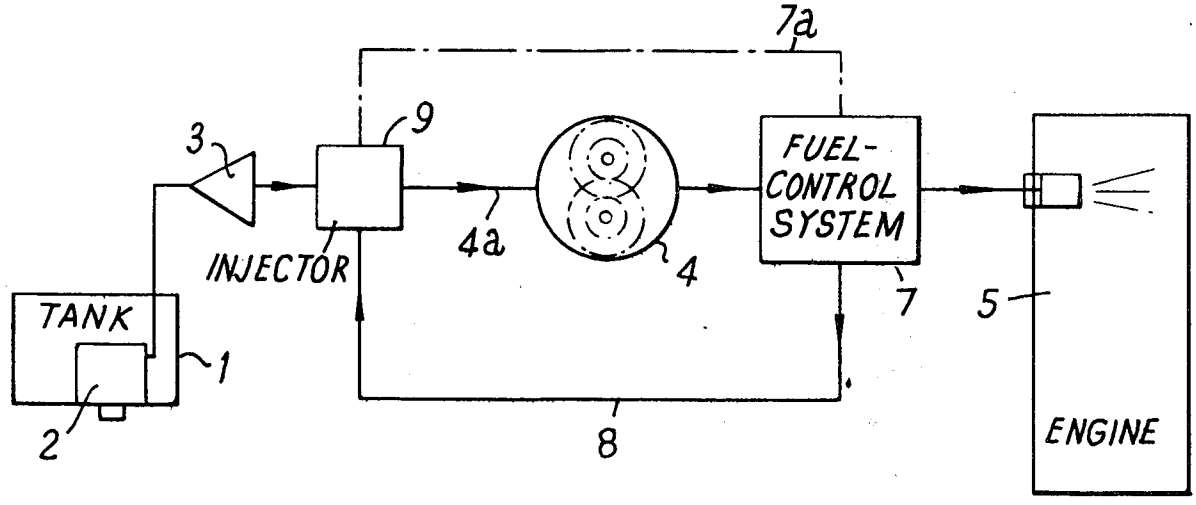


FIG. 1

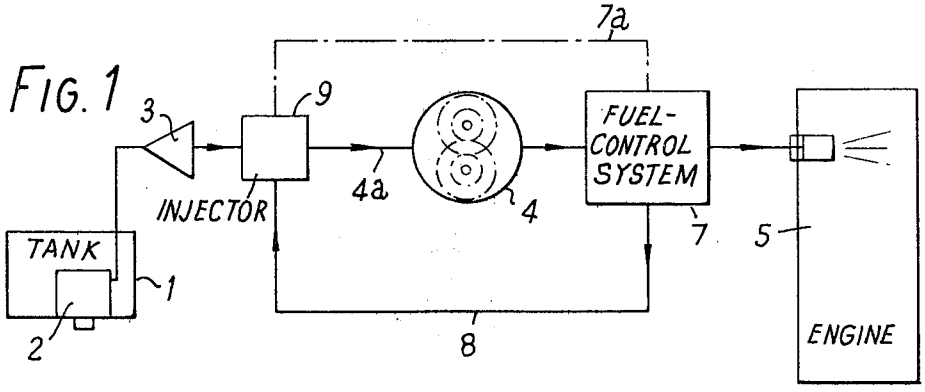


FIG. 2

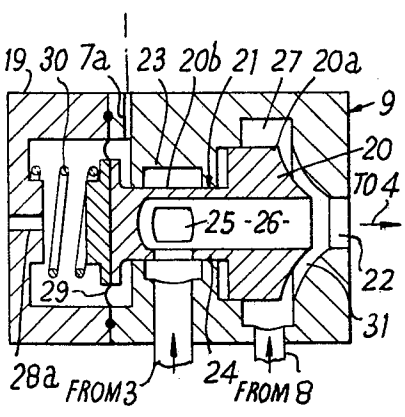


FIG. 3

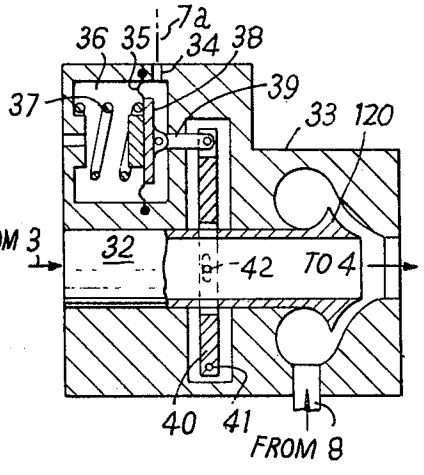
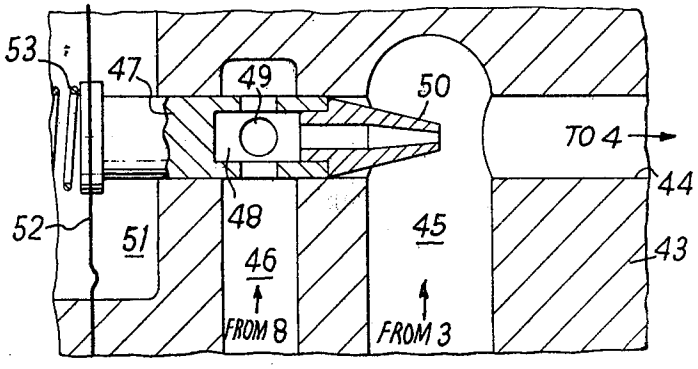


FIG. 4



METERED SUPPLY OF LIQUIDS

This is a continuation of application Ser. No. 318,783 filed Dec. 27, 1972, now abandoned.

This invention relates to a system for the metered supply of a liquid from a source to a load in which the liquid is delivered to the consumer point by a fixed-displacement pump and a variable portion of the delivery of this pump is returned via spill line to the pump inlet. In co-pending U.S. Pat. application No. 174,366, now U.S. Pat. No. 3,736,072 there is described a liquid-supply system of the kind specified in which the whole of the spill-flow is returned to the inlet side of the fixed-displacement pump through an injector device in which the higher pressure of the spill-flow liquid returning from the delivery side to the inlet side of the fixed-displacement pump is utilised to increase the pressure of the liquid from the source at its entry into the pump by the dynamic interaction of the spill-flow liquid with the liquid entering the injector device from the source, and the present invention has for an object to make it possible to maintain in such a system the effectiveness of the utilisation of the spill-flow energy high over a relatively wide range of spill ratios and spill-flow rates. The invention provides at the inlet of a fixed-displacement pump, a hydrodynamic injector device which is equipped with means operable to vary its injection geometry and thereby to so control the rate of the injection-power flow as to maintain optimum efficiency of the injection device over a wide range of rate of flow.

Preferably the geometry is arranged to be automatically varied, at any given speed of the fixed-displacement pump, as a function of the ratio of the spill flow to the total flow delivered by the pump.

Preferably the variable-geometry injector device is so constructed that its adjustment will vary the amount of spill flow passing through the device as well as adapting the geometry of the device to ensure a high injector effect at the spill-flow rate obtained. Accordingly another aspect of the invention consists in the use of an injector device whose geometry is variable in order to maintain a high injector effect over a relatively wide range of ratios between the total flow and the high-speed flow producing the injector action. While the injector according to the present invention may be a jet pump in which the jet nozzle for the high-speed liquid is axially displaceable relative to the throat of the low-speed nozzle through which all the liquid to be injected is arranged to pass, in a preferred form of injector according to the present invention a preferably straight and substantially cylindrical passage for the aspired liquid is arranged to communicate with an annular chamber surrounding the passage and having a conical wall which, at its narrower downstream end, joins the passage wall at an acute angle which ensures that flow along the inner side of this wall has a substantial component of flow in the direction of the flow in the cylindrical passage, and a cone-shaped core body of a similar cone angle is arranged to project coaxially into this annular chamber and is axially displaceable relative thereto so as to form, jointly with the said conical chamber wall, a cone shell of adjustably variable thickness, which forms a passage for the introduction of the high-speed spill flow into the flow of liquid to be aspired. Each of the two coaxial wall portions defining the cone shell has an axial bore constituting part of the passage for the main flow of liquid, and preferably the

transition between the cone-shaped chamber-wall portion and the wall of the cylindrical passage is so arranged as to enable the high-speed spill flow to adhere to the wall of the cylindrical passage by the Coanda effect. It will be readily appreciated that axial displacement of the core body relative to the conical chamber wall will vary the thickness of the layer of spill-flow liquid introduced into the main flow of liquid, thus permitting, by suitable adjustment, to vary the amount of spill flow liquid admitted at a given pressure difference, or if the amount of spill flow is otherwise determined, to maintain the velocity of the spill-flow liquid at the point of entry into the main flow more or less constant when the amount of spill-flow liquid is varied. The invention, although not limited in that way, is of particular value when applied to fuel systems for aircraft-propulsion gas-turbine engines, because the re-conversion of the energy imparted by the fixed-displacement pump to the fuel delivered by this pump in excess to requirements into pressure energy available at the entrance of the fixed-displacement pump greatly reduces dissipation of the said energy and thus the amount of heat introduced into the fuel circulation as compared to previously contemplated systems. The axial adjustment of the displeaceable core body may be effected automatically by a piston element acted-upon by a control pressure that is arranged to vary in accordance with engine data, thus ensuring the required automatic control of the fuel supplied to the engine by varying the amount of spill flow and at the same time effecting an associated alteration of the geometry of the injector device.

In order that the invention may be more readily understood, reference will now be made to the accompanying drawing, in which:

FIG. 1 is a diagram of a fuel-supply system incorporating the present invention in conjunction with an aircraft-propulsion gas-turbine engine.

FIG. 2 is an axial section through an injection device forming part of this fuel system and embodying one aspect of the present invention.

FIG. 3 illustrates a modified form of such injector device, and

FIG. 4 illustrates a variable geometry-jet pump.

Referring now first to FIG. 1, fuel from a tank 1 is raised by a booster pump 2 to a backing pump 3, which supplies it via a line 4*a* to a fixed-displacement pump 4 constituting the main fuel pump of a gas-turbine engine 5. This fuel pump 4 is driven by the engine 5 so as to deliver fuel at a rate proportional to the speed of the engine. In order to adapt the fuel actually supplied to the engine to the varying operating data of the engine, for example to the pressure and temperature of the combustion air supplied to the engine and to the momentary requirements of the engine as to acceleration, a fuel-control system 7 is provided which is arranged to cause the excess of fuel delivered by the pump 4 over the momentary engine requirements to be returned by a spill-flow line 8 to the inlet of the fixed-displacement pump 4 via an injector device 9. In accordance with the present invention, this injector device is constructed as a variable-geometry injector device. This variable geometry device is preferably so constructed as to control the rate of spill flow through line 8 while at the same time adapting its own geometry to this rate in such manner as to maintain a high degree of injector effect. Adjustment of the injector device 9 is effected by a fluid-pressure operated element under the action of a

control-signal pressure; this signal pressure is produced by the fuel-control system 7 and is fed to the injector device 9 by a control-signal line 7*a*.

A suitable form of injector device 9 is illustrated in FIG. 2. It comprises a housing 19, in which a valve element 20 is slidable along a bore 21 towards and away from a flow-outlet passage 22. Fuel from the backing pump 3 is admitted to an annular chamber 23 which is formed in the housing 19, and which surrounds a tubular stem portion 24 of the valve member 20, and from this chamber the fuel enters, via apertures 25 of the stem portion 24, an axial bore 26 which is provided in the valve member 20, and which has an outlet facing the outlet passage 22 of the housing 19. A head portion 20*a* surrounds this bore 26 near its outlet end and tapers in cone fashion towards the said outlet, and this cone-shaped head portion faces a similarly cone-shaped inner face 31 of the housing 19 so that a cone-shell shaped passage is formed between the two said cone faces. This passage leads from an annular chamber 27, which is formed in the housing 19 to surround the head 20*a*, and which communicates with the spill line 8, to the outlet passage 22 of the housing 19. The transition between the cone surface 26 and the outlet passage 22 is so shaped as to cause the flow from chamber 27 to the outlet passage 22 to adhere to the wall of the latter due to the Coanda wall-attachment effect. The rear end of the stem 24 of the valve element 20 projects into a chamber 28, in which it is attached to a diaphragm 29 which divides the length of the chamber 28 into two portions; the portion containing the stem end of the stem 24 is connected to the control-signal line 7*a*, and the other portion is vented to atmosphere at 28*a* and contains a spring 30 which opposes the action exerted upon the diaphragm by the pressure in the first-mentioned portion of the chamber. Increase in the signal pressure in line 7*a* will accordingly move the valve member 20 against the action of the spring 30 to move away from the cone-shaped housing-end wall 31, thus increasing the thickness of the cone-shell shaped passage leading from the annular chamber 27 to the outlet passage 22. More of the fuel delivered by the pump 4 is thereby allowed to return from the spill line 8 into the flow entering the outlet passage 22 of the injector device without thereby substantially altering the velocity at which this spill fuel enters the passage 22.

The arrangement illustrated in FIG. 3 is very similar to that illustrated in FIG. 2 except that the diaphragm 29 of the latter, which acts direct upon the valve stem, and upon which the signal pressure transmitted by line 7*a* acts, has been replaced by a diaphragm 35 which, while similarly acted-upon, is arranged to operate the geometry-control valve element via a lever transmission. The said valve element 120 is slidable in a through bore 32 of the injector-housing body 33, and this bore is arranged to form a continuation of the fuel-inlet line from the backing pump 3. The 90° deflection of the flow from that pump to the main fuel pump 4, which was necessary in the case of FIG. 2, has thus been avoided. The signal-pressure line 7*a* leads to a chamber 34, which is arranged in the housing 33 laterally of the through bore 32, and which is separated by a diaphragm 35 from an extension chamber 36, which is vented to atmosphere at 36*a*, and which contains a loading spring 37. A backing plate 38 attached to the diaphragm 35 is coupled by a link 39, through a lever 40 which moves about a fulcrum 41 in the housing 33, in which the lever 40 extends transversely to the direction of movement of the valve element 120, and this lever is coupled to the valve element 120 by a pin-and-slot connection 42.

FIG. 4 illustrates the application of the invention as to an injector of the jet-pump type. The injector has a housing 43 provided with a main bore 44. This bore, which leads to the inlet of the fixed-diisplacement pump 4, is intersected at right angles by a transverse bore 45, through which the main supply of liquid fuel, coming from the backing pump 3, is admitted to the outlet portion of the main bore 44. The spill flow from spill line 8 is admitted to a jet feed cross bore 46, which intersects the main bore 44 at a point further away from the outlet than the intersection of the main bore 44 with the transverse bore 45. A nozzle member 47, terminating in a jet nozzle 50 facing the outlet end of the bore 44, is slidably accommodated in the main bore 44 of the housing 43 and is formed with an internal cavity 48 which leads to the jet nozzle 50 and which communicates with the cross-bore 46 through apertures 49. At its end opposite to the jet nozzle 50, the nozzle member 47 is arranged to extend from the bore 44 into a control chamber 51 of which one wall consists of a membrane 52 attached to the nozzle member 47. A signal pressure derived from the fuel control system 7 of FIG. 1 is admitted to the control chamber 51 via the line 7*a* or a corresponding line, so that the signal pressure will tend, by acting upon the membrane 52 against a loading spring 53, to increase the distance of the jet nozzle 50 from the outlet of the bore 44, thus varying the geometry of the injector device. In this embodiment the geometry adjustment of the injector device does not substantially affect the resistance of the device to spill flow from the line 8, and thus the rate of this spill flow, and the device is therefore intended for use with a fuel-control device 7 which itself effects the control of the flow rate through the line 8, leaving only the adjustment of the geometry of the injector device to be effected by the signal pressure communicated through line 7*a*.

While a number of embodiments have been described with reference to the accompanying drawing, the invention is not limited to all the details of any of these embodiments. More particularly various features of different embodiments may be combined with each other in a suitable manner.

What we claim is:

1. A system for the metered supply, to a load, of liquid under pressure, which comprises: a source of liquid; a delivery line for the supply of such liquid to the load; a positive-displacement pump having a pump inlet and a pump outlet; delivery-control means having an inlet connected to said pump outlet, a main outlet connected to said delivery line, and a spill outlet arranged to receive substantially all the liquid delivered by said pump except for the liquid which is received by said main outlet, said delivery-control means being operative to variably control the flow to the load through said delivery line by varying the portion of the liquid from said pump outlet received by said spill outlet; and an injector device having a housing formed with an interaction chamber and with a combined-flow outlet extending from said chamber, a main-flow inlet connected to said source, and a power-flow inlet connected to said spill outlet to receive all the liquid passing through said spill outlet, both said inlets leading into said interaction chamber, and said pump inlet being so connected to said combined-flow outlet as to

receive all the flow from said outlet and no other flow, said injector device further including a geometry-varying element having a passage in which one of said inlets terminates said passage in said geometry varying element coaxially facing said combined-flow outlet, said geometry-varying element being axially displaceable relative to said combined-flow outlet; and actuating means which automatically displace, in accordance with operation of the delivery-control means to provide a different rate of spill flow, said geometry-varying element in the direction in which the resulting geometry variation improves the pressure-raising effect of the injector device at said different rate of spill flow.

2. A system as claimed in claim **1,** which includes a pressure-sensitive actuating device for the geometry-varying element.

3. A system as claimed in claim **1,** for the metered supply of liquid fuel to a gas-turbine engine of an aircraft, wherein said delivery-control means are fuel-regulator means operative to pass through said spill outlet the excess of the fuel delivered by said positive-displacement pump over the momentary fuel requirement of the engine.

4. A system as claimed in claim **3,** wherein said geometry-varying element co-operates with the injector housing to form jointly therewith a variable-area restrictor for the flow through said injector device, and which includes a pressure-sensitive actuating device for said geometry-varying element, said fuel-regulating means being arranged to have a pressure outlet connected to said pressure-sensitive actuating device to control the setting of said geometry-varying element and thus to control the flow through said spill outlet by variation of the area of said restrictor.

5. A system as claimed in claim **1,** wherein said geometry-varying element co-operates with the housing of the injector device to form jointly therewith a variable-area restrictor for the flow through said injector device.

6. A system as claimed in claim **1,** wherein said combined-flow outlet has a peripheral wall surface extending from said chamber, and said geometry-varying element has an outer wall surface co-operating with said peripheral wall surface to form jointly therewith an annular orifice, at least one of said wall surfaces being tapered so that axial displacement of said geometry-varying element will vary the size of said annular orifice.

7. A system as claimed in claim **1,** wherein the inlet terminating in said geometry-varying element is the main-flow inlet, said element being formed with a coaxial cone surface, while a complementary cone surface is provided at said combined-flow outlet to form with the first-mentioned cone surface an annular nozzle of adjustably variable radial width, the power-flow inlet being arranged to terminate in this nozzle.

8. A system as claimed in claim **7,** which further comprises an actuating device for said geometry-varying element, said actuating device including an enclosure forming a chamber and having a movable wall member, and means at least operatively connecting said wall member to the member on which one of said cone surfaces is provided.

9. A system as claimed in claim **8,** wherein said main inlet extends to the passage in the geometry-varying element substantially in a straight line coaxial with the said passage, and wherein said connecting means are arranged wholly outside the cross-section of said main-flow inlet.

10. A system as claimed in claim **8,** wherein the geometry-varying element is equipped with a coaxial stem, said movable wall surface being fixed to said coaxial stem and wherein said passage extends from a point inside the stem to the end facing said combined-flow outlet, said stem having an aperture establishing communication between the main-flow inlet of the injector device and the said passage in said stem.

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