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FIG 10B
F1E 10A1 36 5
F1F 1B5B1 2B EQ

(54) FLUID DELIVERY SYSTEMS

(71) We, SUNDSTRAND CORPORATION, a corporation organised and existing under the laws of the State of Delaware, United States of America, of 4751, Harrison Avenue, Rockford, Illinois 61101, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to fluid delivery systems and particularly to fluid delivery systems that are suitable for delivery of fuel from a fuel tank to an aircraft engine.

The invention provides a system for delivering fluid from a fluid reservoir to a fluid utilising means, the system comprising a positive displacement pump, an ejector pump for delivering fluid from the fluid reservoir to the positive displacement pump, means for directing a first part of the fluid delivered by the positive displacement pump to the fluid utilising means and a second part of the fluid delivered by the positive displacement pump to a nozzle of the ejector pump, a first flow control valve for controlling the volume of the first part of the fluid and a second flow control valve responsive to the pressure differential across the nozzle for maintaining a constant rate of fluid flow through the nozzle.

Such a fluid delivery system is particularly suitable for delivery of fuel from a fuel tank to an aircraft engine. The use of an ejector pump for boost, as opposed to an electrically operated boost pump, is safer in the event of a forced or crash landing, since the ejector pump can operate only when the positive displacement pump is operating. An electrical boost pump would continue to pump fuel increasing the fire risk but the ejector pump will not pump fuel from the tank.

The provision of constant flow to the nozzle of the ejector pump enables design of the ejector pump to be optimized, and the performance of the ejector pump not to be affected by atmospheric variations caused by

changes of altitude or by variations in engine demand for fuel.

Fluid not utilized by the fluid utilizing means not delivered to the ejector pump nozzle may be returned to the positive displacement pump. This fluid may be returned to the main inlet of the positive displacement pump, that is the inlet supplied by the ejector pump, or to auxiliary inlets of the positive displacement pump. This, and particularly the latter return, ensures more complete filling of the pumping chambers of the positive displacement pump, and in the case when the fluid is fuel therefore reduces the amount of vapour pumped, rendering the fuel more nearly a one-state (liquid) flow as is desirable.

Fluid delivery systems according to the invention can be embodied in a number of different ways. For example, in one form of fluid delivery system according to the invention a conduit extends from the positive displacement pump to both the inlet of the second flow control valve and the nozzle of the ejector pump and a conduit extends from the outlet of the second flow control valve to the main inlet or the auxiliary inlets of the positive displacement pump. Alternatively a first conduit may extend from the positive displacement pump to the nozzle of the ejector pump, a second conduit extending from the positive displacement pump to the main inlet of the positive displacement pump or the auxiliary inlets of the positive displacement pump and the second flow control valve is included in the first conduit. In embodiments in which fuel returned to the positive displacement pump is returned to the auxiliary inlets thereof, a conduit may extend from that leading to the auxiliary inlets to the main inlet and include a relief valve.

The invention is illustrated with reference to the drawings, of which:

Figure 1 is a schematic view of fluid delivery system according to the invention;

Figure 2 is a fragmentary central section of a structural unit embodying the ejector

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boost pump and the priority valve shown in Figure 1;

Figure 3 is a cross sectional view of a positive displacement pump in the form of rotary intermeshing gear pump of the type used in the schematic circuit of Figure 1;

Figure 4 is a schematic view of another fluid delivery system according to the invention;

Figure 5 is a schematic view of yet another fluid delivery system according to the invention; and

Figure 6 is a schematic view of a still further fluid delivery system according to the invention.

With reference to Figures 1 to 3 of the drawings, a positive displacement pump 10 has an outlet 10a connected to a discharge line 11 which leads to a fuel control 12 for controlling the rate of fuel supply to a load, such as an aircraft engine 15. Fuel not delivered to the engine by the fuel control 12 is directed to a bypass line 16 for return to the fluid delivery system.

The fuel supply for the engine 15 is stored in a tank 20 which is connected by a line 21 to a boost stage 22. The boost stage 22 is in the form of an ejector boost pump having an outlet 23 connected to a line 24 which extends to an inlet 25 of the positive displacement pump 10 by way of line sections 24a and 24b extending, respectively, to and from an interstage system 26. The interstage system 26 comprises heat exchangers, filters and other necessary or desirable components of a fuel system.

The boost stage ejector pump is shown in detail in Figure 2 and comprises a casing 30 having a plenum chamber 31 connected to the line 21 leading from the tank 20 and a nozzle 32 defining an orifice opening into the plenum chamber 31, and a mixing tube 33 downstream of the plenum chamber 31 and functioning to provide a momentum exchange between the fuel which flows through the nozzle 32 of the boost stage 22 and that which flows into the plenum chamber 31 from the tank 20.

Fuel representing part of the fuel displacement of the main engine fuel pump 10 is caused to flow through the nozzle 32 by an extension 35 of the bypass line which extends to the inlet of the nozzle 32 as shown in Figure 1.

The fuel entering the plenum chamber 31 from the tank 20 may be a two-state flow with both liquid and vapour phases. The ejector pump functions to increase the pressure of the fuel thereby returning the vapour phase into the liquid phase and obtaining a single-state flow for delivery to the main fuel pump 10.

A branch line 40 extends from the bypass line 16 and has a motive flow source control valve positioned therein which, in the

embodiment of Figure 1, is a priority valve 41. The priority valve 41, shown in detail in Figure 2, has a valve member 42 urged against a valve seat 43 by a spring 44 which is of relatively light force up to certain design pressures to close off the branch line 40. The branch line 40 downstream of the priority valve is connected to a pair of auxiliary inlets 45 and 46 for the main engine fuel pump 10 and to the inlet line 24b by way of a relief valve 47 whereby there cannot be an excessive pressure build-up in the branch line 40.

The valve member 42 of the priority valve 41 is urged towards a valve closed position against the valve seat 43 by the spring 44 and is responsive to a pressure differential across the nozzle 32 to maintain a uniform rate of fluid flow through the nozzle 32. The pressure in the bypass line 16 acts on the valve member 42 in a direction tending to open the valve and in opposition to the spring while the pressure downstream of the nozzle and existing in the plenum chamber 31 is applied to the opposite end of the valve member 42 through sensing passages 50 and 51 in the casing 30. The priority valve 41 functions to provide a constant rate of fuel flow through the nozzle. If the flow through the nozzle 32 drops, the pressure downstream of the nozzle 32 becomes more relative to that upstream of the nozzle 32 and this causes the valve member 42 of the priority valve 41 to move towards the valve seat 43 to reduce the flow to the auxiliary inlets 45 and 46 and increase the flow through the nozzle 32. If the flow through the nozzle 32 increases, pressure upstream relative to the pressure downstream increases, and the priority valve 41 is opened more, to direct more fluid to the auxiliary inlets 45 and 46 and reduce the flow through the nozzle. The flow delivered by the fuel pump 10 to the fuel control 12 and the desired rate of flow through the nozzle 32 are set whereby the bypass line 16 always has sufficient fuel to provide proper flow to the nozzle 32, with some excess going to the auxiliary inlets 45 and 46. As altitude increases, the engine utilizes less fuel and the fuel control 12 will cause an increased amount of fuel to flow to the bypass line 16, with the priority valve 41 providing for an increased flow to the auxiliary inlets 45 and 46 to maintain the uniform flow to the boost stage. In Figure 2, the branch line 40 is shown as including a portion of the valve bore upstream of the valve seat 43 and an annular chamber surrounding the valve member 42 immediately downstream of the valve seat 43.

The positive displacement pump 10 is shown in detail in Figure 3 and is of the kind described in United States Patent Specification No. 3,182,596. The pump 10

has rotary intermeshing gear units 60 and 61 rotating in the direction of the arrows, and the branch line 40 is connected into the casing of the pump to supply the auxiliary inlets 45 and 46. The auxiliary inlets 45 and 46 are out of communication with the inlet 25, being spaced at a sufficient arcuate distance (at least one gear tooth space) from the inlet 25 to provide a seal. With this construction, fuel is supplied through the auxiliary inlets 45 and 46 at a higher pressure than through the inlet 25 to successive pumping chambers after initial filling from the inlet 25 to assure complete filling of the pumping chambers between gear teeth and to prevent formation of voids in the fuel which might otherwise occur because of vapour. In the fluid delivery system shown in Figures 1 to 3, fuel is only drawn from the tank 20 when the positive displacement pump 10 is operating. Additionally, there are only relatively low pressure suction feed lines between the tank 20 and positive displacement pump 10 so that fire hazard created when small arms fire penetrates the feed lines, for example in a military helicopter, is reduced.

The uniform rate of fluid flow through the nozzle 32 enables the design of the boost stage ejector pump to be optimized for peak efficiency and, at the same time, excess flow in the bypass line 16 may be directed to the auxiliary inlets 45 and 46 through the use of priority valve 41 to ensure full pumping action of the fuel pump, even with vapour being present in the fuel.

In the embodiment of Figure 4, the same reference numerals have been applied as in the embodiment of Figures 1 to 3 with respect to structure common to the two embodiments.

In this embodiment, the branch line 40 downstream of the priority valve 41 connects directly into line 24b leading to the inlet 25 of the fuel pump 10. This embodiment does not have the auxiliary inlets to the positive displacement fuel pump 10 and the relief valve associated therewith.

The priority valve 41 functions to maintain a uniform rate of flow through the bypass line 16 to the nozzle 32, with excess flow being returned to the inlet 25 of the fuel pump 10.

In the embodiment of Figure 5, structure which is the same as that in the embodiment of Figures 1 to 3 has been given the same reference numerals.

In this embodiment, the bypass line 16, leading from the fuel control 12 is connected to the auxiliary inlets 45 and 46 for the fuel pump 10. Fuel is not derived from the bypass line 16 in order to supply the nozzle 32. In this embodiment, the motive flow source control valve is a flow control valve 75 connected in a fuel line 76 extending be-

tween the discharge line 11 of the fuel pump 10 and the nozzle 32, with a part 77 of the fuel line being downstream of the flow control valve 75. A sensing line 80 comparable to sensing lines 50 and 51 of the embodiment of Figure 1 to 3, directs the pressure existing in the plenum chamber 31 to the flow control 75 whereby the flow control valve 75 operates in response to the pressure differential across the nozzle 32 to deliver a constant rate of fuel flow from the fuel in discharge line 11 to the nozzle 32. The nonutilized fuel directed by the fuel control 12 to the bypass line 16 is delivered to the auxiliary inlets 45 and 46 for ensuring complete filling of the pumping chambers of the pump 10.

The embodiment of Figure 6 is substantially the same as the embodiment of Figure 5, with the flow control valve 75 positioned in the fuel line 76, which connects to the fuel pump discharge line 11. The fuel directed by fuel control 12 to the bypass line 16 flows directly to the line 24b for flow into the inlet 25 of the fuel pump 10. The operation of the embodiment of Figure 6 is the same as that of Figure 5, except that non-utilized flow from the fuel control 12 is returned to the inlet 25 of the fuel pump 10 and the fuel pump 10 does not have the auxiliary inlets 45 and 46.

With the embodiments disclosed herein, over-all performance of the fluid delivery system is optimized by the ability to use the best ejector stage design resulting from constant fuel flow through the nozzle thereof and with non-utilized fuel being returned to the main fuel pump.

Further advantages are derived, when required, through the flow of a portion of the non-utilized fuel pumped by the main fuel pump to auxiliary inlets of the fuel pump to ensure complete filling of the pumping chambers.

WHAT WE CLAIM IS:—

1. A system for delivering fluid from a fluid reservoir to a fluid utilising means, the system comprising a positive displacement pump, an ejector pump for delivering fluid from the fluid reservoir to the positive displacement pump, means for directing a first part of the fluid delivered by the positive displacement pump to the fluid utilising means and a second part of the fluid delivered by the positive displacement pump to a nozzle of the ejector pump, a first flow control valve for controlling the volume of the first part of the fluid and a second flow control valve responsive to the pressure differential across the nozzle for maintaining a constant rate of fluid flow through the nozzle.

2. A fluid delivery system according to claim 1 further comprising means for returning to the positive displacement pump a

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has rotary intermeshing gear units 60 and 61 rotating in the direction of the arrows, and the branch line 40 is connected into the casing of the pump to supply the auxiliary inlets 45 and 46. The auxiliary inlets 45 and 46 are out of communication with the inlet 25, being spaced at a sufficient arcuate distance (at least one gear tooth space) from the inlet 25 to provide a seal. With this construction, fuel is supplied through the auxiliary inlets 45 and 46 at a higher pressure than through the inlet 25 to successive pumping chambers after initial filling from the inlet 25 to assure complete filling of the pumping chambers between gear teeth and to prevent formation of voids in the fuel which might otherwise occur because of vapour. In the fluid delivery system shown in Figures 1 to 3, fuel is only drawn from the tank 20 when the positive displacement pump 10 is operating. Additionally, there are only relatively low pressure suction feed lines between the tank 20 and positive displacement pump 10 so that fire hazard created when small arms fire penetrates the feed lines, for example in a military helicopter, is reduced.

The uniform rate of fluid flow through the nozzle 32 enables the design of the boost stage ejector pump to be optimized for peak efficiency and, at the same time, excess flow in the bypass line 16 may be directed to the auxiliary inlets 45 and 46 through the use of priority valve 41 to ensure full pumping action of the fuel pump, even with vapour being present in the fuel.

In the embodiment of Figure 4, the same reference numerals have been applied as in the embodiment of Figures 1 to 3 with respect to structure common to the two embodiments.

In this embodiment, the branch line 40 downstream of the priority valve 41 connects directly into line 24b leading to the inlet 25 of the fuel pump 10. This embodiment does not have the auxiliary inlets to the positive displacement fuel pump 10 and the relief valve associated therewith.

The priority valve 41 functions to maintain a uniform rate of flow through the bypass line 16 to the nozzle 32, with excess flow being returned to the inlet 25 of the fuel pump 10.

In the embodiment of Figure 5, structure which is the same as that in the embodiment of Figures 1 to 3 has been given the same reference numerals.

In this embodiment, the bypass line 16, leading from the fuel control 12 is connected to the auxiliary inlets 45 and 46 for the fuel pump 10. Fuel is not derived from the bypass line 16 in order to supply the nozzle 32. In this embodiment, the motive flow source control valve is a flow control valve 75 connected in a fuel line 76 extending be-

tween the discharge line 11 of the fuel pump 10 and the nozzle 32, with a part 77 of the fuel line being downstream of the flow control valve 75. A sensing line 80 comparable to sensing lines 50 and 51 of the embodiment of Figure 1 to 3, directs the pressure existing in the plenum chamber 31 to the flow control 75 whereby the flow control valve 75 operates in response to the pressure differential across the nozzle 32 to deliver a constant rate of fuel flow from the fuel in discharge line 11 to the nozzle 32. The nonutilized fuel directed by the fuel control 12 to the bypass line 16 is delivered to the auxiliary inlets 45 and 46 for ensuring complete filling of the pumping chambers of the pump 10.

The embodiment of Figure 6 is substantially the same as the embodiment of Figure 5, with the flow control valve 75 positioned in the fuel line 76, which connects to the fuel pump discharge line 11. The fuel directed by fuel control 12 to the bypass line 16 flows directly to the line 24b for flow into the inlet 25 of the fuel pump 10. The operation of the embodiment of Figure 6 is the same as that of Figure 5, except that non-utilized flow from the fuel control 12 is returned to the inlet 25 of the fuel pump 10 and the fuel pump 10 does not have the auxiliary inlets 45 and 46.

With the embodiments disclosed herein, over-all performance of the fluid delivery system is optimized by the ability to use the best ejector stage design resulting from constant fuel flow through the nozzle thereof and with non-utilized fuel being returned to the main fuel pump.

Further advantages are derived, when required, through the flow of a portion of the non-utilized fuel pumped by the main fuel pump to auxiliary inlets of the fuel pump to ensure complete filling of the pumping chambers.

WHAT WE CLAIM IS:—

1. A system for delivering fluid from a fluid reservoir to a fluid utilising means, the system comprising a positive displacement pump, an ejector pump for delivering fluid from the fluid reservoir to the positive displacement pump, means for directing a first part of the fluid delivered by the positive displacement pump to the fluid utilising means and a second part of the fluid delivered by the positive displacement pump to a nozzle of the ejector pump, a first flow control valve for controlling the volume of the first part of the fluid and a second flow control valve responsive to the pressure differential across the nozzle for maintaining a constant rate of fluid flow through the nozzle.

2. A fluid delivery system according to claim 1 further comprising means for returning to the positive displacement pump a



third part of the fluid delivered by the positive displacement pump.

3. A fluid delivery system according to claim 2 in which the means for returning fluid to the positive displacement pump are adapted to return the fluid to a main inlet of the positive displacement pump, which main inlet is that supplied by the ejector pump.

4. A fluid delivery system according to claim 3 in which a conduit extends from the positive displacement pump to both the inlet of the second flow control valve and the nozzle of the ejector pump and a conduit extends from the outlet of the second flow control valve to the main inlet of the positive displacement pump.

5. A fluid delivery system according to claim 3 in which a first conduit extends from the positive displacement pump to the nozzle of the ejector pump, a second conduit extends from the positive displacement pump to the main inlet of the positive displacement pump, and the second flow control valve is included in the first conduit.

6. A fluid delivery system according to claim 2 in which the means for returning fluid to the positive displacement pump are adapted to return the fluid to a pair of auxiliary inlets of the positive displacement pump, which auxiliary inlets are not in fluid communication with the main inlet supplied by the ejector pump.

7. A fluid delivery system according to claim 6 in which a conduit extends from the positive displacement pump to both the inlet of the second flow control valve and the nozzle of the ejector pump and a conduit extends from the outlet of the second flow control valve to the auxiliary inlets of the positive displacement pump.

8. A fluid delivery system according to claim 7 in which a conduit extends from the outlet of the second flow control valve to the main inlet of the positive displacement pump and includes a relief valve.

9. A fluid delivery system according to claim 6 in which a first conduit extends from the positive displacement pump to the nozzle

of the ejector pump, a second conduit extends from the positive displacement pump to the auxiliary inlets of the positive displacement pump, and the second flow control valve is included in the first conduit.

10. A fluid delivery system according to claim 9 in which a branch conduit extends from the second conduit to the main inlet of the positive displacement pump and includes a relief valve.

11. A fluid delivery system according to any of claims 4, 7 or 8 in which the valve member of the second flow control valve is urged in one direction by the pressure in a plenum of the ejector pump into which plenum the nozzle opens and by a spring, and is urged in the other direction by the pressure in the conduit which extends from the positive displacement pump to the inlet of the second flow control valve.

12. A fluid delivery system according to any of claims 5, 9 or 10 in which the valve member of the second flow control valve is urged in one direction by the pressure in a plenum of the ejector pump into which plenum the nozzle opens and by a spring, and is urged in the other direction by the pressure in the first conduit.

13. A fluid delivery system according to any preceding claim being a fuel delivery system for an aircraft.

14. A fluid delivery system substantially as described herein with reference to Figures 1 to 3 of the drawings.

15. A fluid delivery system according to claim 14, modified as described herein with reference to Figure 4 of the drawings.

16. A fluid delivery system substantially as described herein with reference to Figures 2, 3 and 5 of the drawings.

17. A fluid delivery system according to claim 16, modified as described herein with reference to Figure 6 of the drawings.

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