July 12, 1960 R. W. WILSON 2,944,597

FUEL SYSTEM

Filed Feb. 20, 1957 3 Sheets-Sheet 1

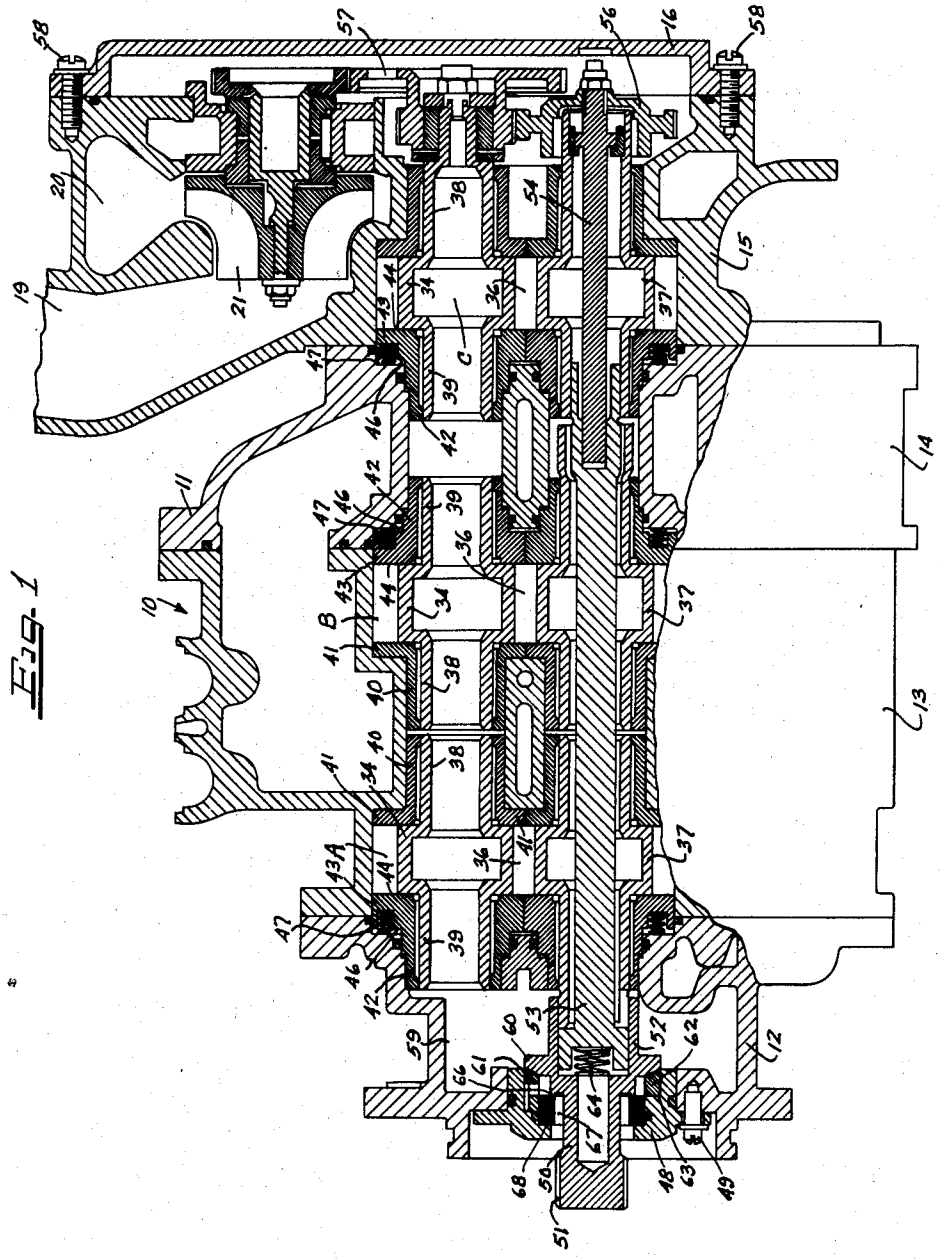


Fig. 1

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FUEL SYSTEM

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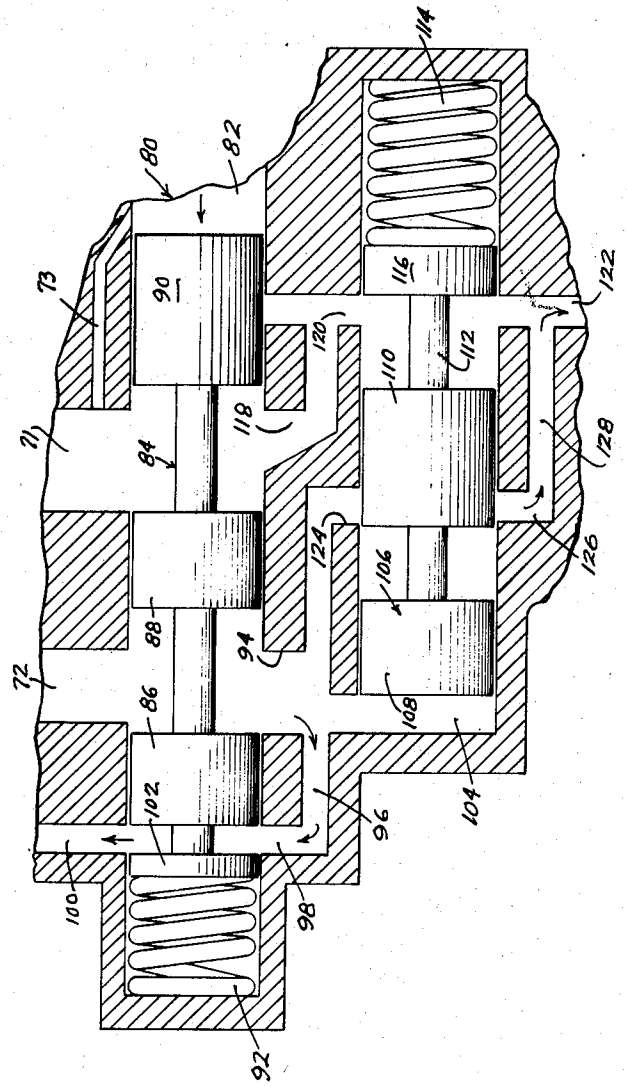


Fig. 2

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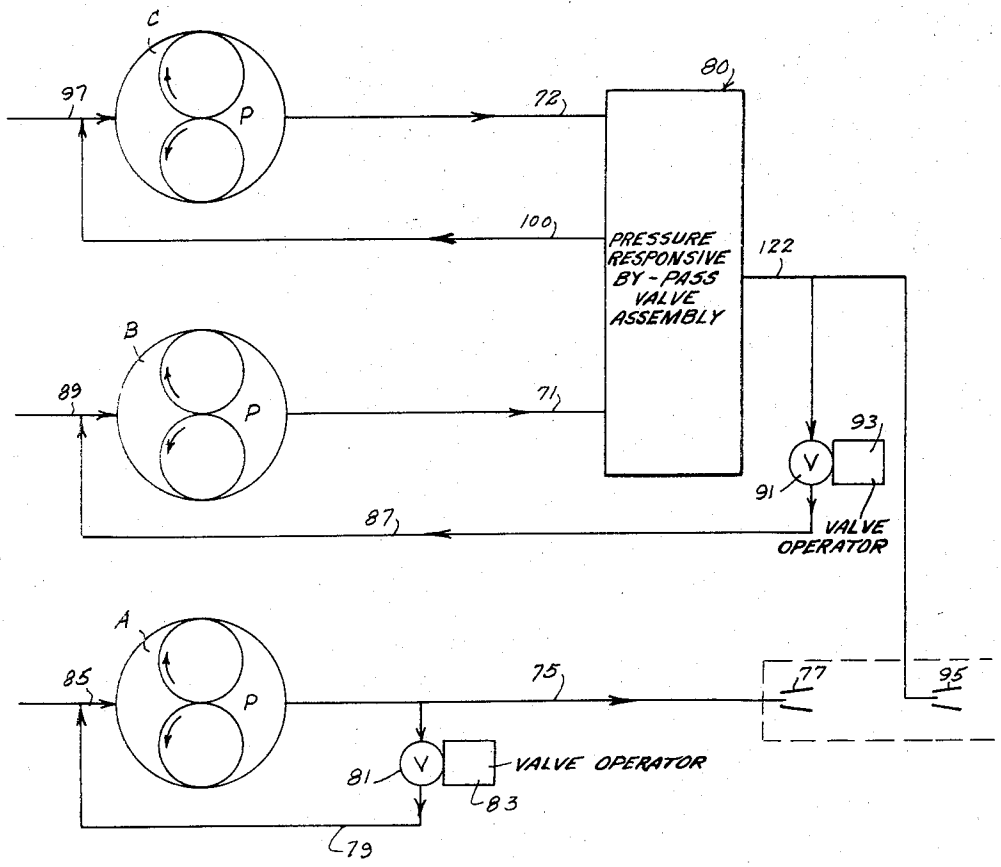
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By

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FUEL SYSTEM

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Fig. 3



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FUEL SYSTEM

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7 Claims. (Cl. 158—36.4)

This invention relates to fuel systems and more particularly to a combination pump of the type utilized in an aircraft fuel system wherein three separate pumping units are provided, one of the pumping units providing fuel for a main burner, another of the pumping units providing fuel for an afterburner, and the third pumping unit providing fuel for the afterburner at periods of peak demand.

This invention is primarily directed to a combination pump of the type having three separate pumping units including a main pump unit for the main burner, an afterburner pump unit which is continuously operative to supply fuel to the afterburner, and an auxiliary afterburner pump unit which may be selectively actuated in response to demand pressure of the principal afterburner pumping unit. Demand pressure, as referred to herein, is the pressure of the fuel in the delivery line, which pressure is regulated in response to a control signal to satisfy demand for fuel for more or less power. For example, in systems where a positive displacement pump is used, the fuel delivered to the burner may be controlled by a by-pass valve, and as the by-pass valve is closed in response to a control signal, which manifests a demand for more fuel, the pressure increases. The pressure increases with demand also in a system where a fuel pump is speeded up to satisfy a demand for power increase.

In particular, this invention involves the provision of a combination pump of the stated type in which a valve assembly is formed integrally with the pump for affording recirculation of the discharge by the auxiliary afterburner pump unit at a pressure substantially less than the working pressure of the unit and affording activation of the auxiliary afterburner pumping unit in response to a value of pressure corresponding to a predetermined value of pressure of fluid discharged by the principal afterburner pumping unit.

A principal object of the invention is to provide a fuel system employing a pump of the combination type in which the output of the auxiliary afterburner pumping unit is selectively recirculated when not required for afterburner operation at a relatively low pressure, substantially lower than the normal output pressure, so that the inevitable increase in temperature of the fuel due to working is minimized.

According to the present invention, the combination pump incorporates a flow transferring means in the pump casing for selectively paralleling the outlet of the auxiliary afterburner pumping unit with the outlet of the principal afterburner pumping unit. For example, the outlets of the principal afterburner pumping unit and the auxiliary afterburner pumping unit comprise a pair of longitudinally spaced openings selectively controllable by a valve assembly which permits continuous flow of the discharge from the principal afterburner pumping unit, while normally bypassing the discharge from the auxiliary afterburner pumping unit back to interstage or inlet pressure. Upon a predetermined increase in pressure of the discharge from the principal afterburner pumping

unit, the valve assembly is actuated to terminate the bypassing of the discharge from the auxiliary afterburner pumping unit to parallel this discharge with the discharge from the principal afterburner pumping unit. The valve assembly includes a spool or pilot slidably mounted within a cylinder and biased in one direction by a spring. The spool or pilot is motivated by fuel discharged from the principal afterburner pumping unit in opposition to the force of the spring so that pressure is brought to bear upon another spool or pilot which is then moved axially within another cylinder to afford a joinder of the discharges from the several afterburner pumping units.

Other objects, features and advantages of the present invention will be more fully apparent from the following detailed description taken in connection with the accompanying drawings, in which:

Figure 1 is a sectional elevational view, partly broken away, of a combination pump embodying the fuel system of the present invention;

Figure 2 is a greatly enlarged sectional diagrammatic view of a valve assembly forming a part of the combination pump of Figure 1;

Figure 3 is a schematic showing of a fuel system illustrating a system of the type therein the principles of the invention may be utilized.

As shown on the drawings:

The pump forming a part of the fuel system of the present invention is indicated generally by the reference numeral **10** and comprises a casing or housing **11** which includes a plurality of connected housing parts identified on Figure 1 by the reference numerals **12**, **13**, **14**, **15** and **16**.

The housing part indicated at **15** has an inlet **19** which may be connected to a suitable fluid supply conduit. The inlet **19** is in communicaiton with a volute pumping chamber **20** in which is rotated a centrifugal impeller **21** for increasing the pressure of the fluid to a predetermined level.

In the housing parts **12**, **13** and **14** and **15** there are formed three longitudinally spaced pumping cavities for three separate gear pumping units indicated generally by the reference characters A, B and C, respectively.

Fuel may be supplied by the pumping unit A to a main burner of an aircraft propulsion engine utilizing jet burners. The pumping unit B supplies fuel at all times to an afterburner forming a part of the environment of the present fuel system. The pumping unit C selectively supplies fuel to the afterburner at periods of peak demand, such as at take-off or when accelerating. Each of the gear pumping units A, B, and C are substantially identical with respect to structural features, and, accordingly, common reference numerals will be used wherever possible.

Each gear pumping unit comprises a driven gear **34** meshing at an area of intermesh **36** with a driving gear **37**. Extending axially outwardly from the hub portion of each respective driving and driven gear is a first shaft extension **38** and a second shaft extension **39**. Each shaft extension **38** is journalled by a stationary bushing member **40** received in a corresponding housing bore and having a flange **41** providing a sealing face for engaging and sealing against the adjoining side face of the gear.

Each gear shaft extension **39** is journalled in the casing by a movable pressure-loaded bushing **42** having a flange **43** providing a front face **44** for engaging and sealing against an adjoining gear side face and a rear face **46** which together with means including the housing **11** forms a pressure control chamber **47** communicating with pump-generated discharge pressure to pressure load the movable bushing **42** into sealing relationship against the side face of the gear.

The housing part 12 is closed by a cover member 48 assembled in firm assembly to the housing part 12 by a plurality of fasteners 49. A shaft driving member 50 has a splined portion 51 adapted to be connected to a prime mover on the outside of the pump and extends inwardly into the housing part 12 for connection to the gear pumping units A, B and C. The driving member 50 has a collar portion 52 splined to a quill shaft 53 which extends through hollow portions of the driving gears 37 of the gear pumping units A and B. The quill shaft 53 is in turn splined to the driving gear of the gear pumping unit C and also to a second quill shaft member 54 which extends through the gear pumping unit C and has attached thereto at one end a gear 56 forming part of a gear train 57 which is operative to drive the centrifugal impeller 21. Thus, the gears of the gear pumping units A, B and C are rotated at a speed corresponding to a rated efficiency speed for intermeshing gears and the centrifugal impeller 21 is rotated at a much higher speed corresponding to the speed for greatest rated efficiency of centrifugal impellers. The housing part 16 forms a cover for the gear train 57 and may be fastened to the housing part 15 by a plurality of fasteners indicated at 58.

The shaft extensions and the hubs of the driving gears 37 are hollow and the shaft extensions 38 and 39 as well as the hub portions of the driven gears 34 are also hollow, thereby proving through passages the length of the pump housing 11. Thus, all of the internal cavities such as the cavity 59 in the pump housing 11, which are separated from the actual outlet portions of the pump can be communicated with a source of low pressure such as the pump inlet to facilitate the use of low pressure seals for minimization of leakage and other sealing problems.

Moreover, this arrangement affords another advantageous structural and functional feature which permits the flooding and lubrication of a thrust bearing associated with the driving means just described. In reference to this arrangement, it should be noted on Figure 1 that the driving member 50 has a radially outwardly extending annular flange 60 having at one side thereof a chamfered bearing face 61 engaging a ring of bearing material 62 seating in an annular recess 63 formed in the cover member 48. A coil spring 64 is located in a recess jointly provided by the driving member 50 and the quill shaft 53 so that one end of the coil spring 64 is bottomed against the driving member 50 and the opposite end is bottomed against the quill shaft 53, thereby maintaining a continuous biasing force between the two parts.

The driving member 50 is provided with an axially extending annular lip 66 and the cover member 48 is provided with an additional recess 67 in which is mounted a sealing assembly 68, the sealing assembly 68 engaging against the lip 66 and effecting an adequate seal between the cover member 48 and the driving member 50. Since the sealing assembly 68 is located outside of the thrust bearing formed by the flange 60 and the bearing 61, the thrust bearing can be flooded with the fluid contained within the cavity 59 to insure adequate lubrication and cooling even though the pump is operated at high speeds.

Referring now more particularly to Figure 2 in conjunction with Figure 1, each of the pump units A, B and C has a separate outlet formed by cored areas or recesses within the housing parts 13 and 14. The outlet of the pumping unit A provides fuel to the main burner in the conventional manner and need not be discussed in detail. The outlets of the pump units B and C are shown somewhat diagrammatically in Figure 2 and are indicated by reference numerals 71 and 72 respectively.

As illustrated in Figure 3, the pump A is connected to discharge to a delivery line 75 which is connected to a main burner nozzle 77. The quantity of fuel delivered from the pump may be controlled such as by the provision of a by-pass line 79 leading from the discharge line 75 to a pump intake line 85. The quantity of flow by-passed through the line 79 is determined by the opening of a valve 81 which is operated by a control 83.

The output or discharge of pump B is connected to the line 71 which connects to the valve assembly 80, as also illustrated in Figure 2. The output conduit 122 from the valve assembly 80 connects to an afterburner nozzle 95. During periods of low fuel consumption of the nozzle 95, the delivery of fuel from the pump B is controlled through a by-pass line 87 which connects to the conduit 122 and connects to the pump intake 89. Flow through this by-pass line is controlled by a by-pass valve 91 operated by a control 93. With this arrangement, as the demand for fuel increases, the control 93 closes the valve 91, and a resulting increase in the discharge pressure of the pump B results.

The pump C has its discharge connected to the line 72 which connects to the valve assembly 80. The by-pass return line 100 connects to a pump intake line 97.

According to the present invention, the outlets 71 and 72 are in communication with the valve assembly 80 which is operated to afford continual flow from the pumping unit B and recirculation of the discharge from the outlet 72 of the pumping unit C at predetermined discharge pressures of the pumping unit B. In addition, the valve assembly 80 is operative to effect joinder of the discharges from the pumping units B and C at certain demand pressures of the pumping unit B. To this end, the valve assembly 80 is provided with a cylindrical bore 82 in which is slidably mounted a valve spool or pilot 84 having spaced control portions 86, 88 and 90. The valve spool or pilot 84 is normally retained in the position shown in Figure 2 by a compression spring 92 which is opposed by fluid received within the bore 82 at the right side of the control portion 90 from the outlet 71 by any suitable means such as a cored passage 73 or the like. In this position of the valve spool 84, fuel discharged from the pumping unit C is free to flow radially through the bore 82 and out a port 94 formed in the valve assembly casing in register with the outlet 72, through a longitudinally extending passage 96 and thence back to the inlet of the pumping unit C through a port 98 and a registering port 100, a passage being formed through the bore 82 by the left side of the control portion 86 and a disk 102 against which the compression spring 92 abuts.

The valve assembly 80 has another cylindrical bore 104 in which is slidably mounted a valve spool or pilot 106 having control portions 108 and 110 maintained in spaced relation on a central shaft 112. The spool 106 is normally maintained in the position shown by a compression spring 114 which abuts against a disk 116 mounted at one end of the shaft 112 and is opposed by the relatively low pressure of the fluid discharged from the pumping unit C when the spool 84 is in the position shown. In the position shown, discharge from the pumping unit B may at all times flow across the bore 82, through a passage 118 and thence into the passage 120 which is in register with a passage 122 at the opposite side of the bore 104. Thus, fuel is supplied to the afterburner through the passage 122 at all times.

When the demand pressure of the pumping unit B increases, the fuel at the right side of the control portion 90 urges the valve spool 84 to the left, as viewed in Figure 2, thus compressing the spring 92 and closing off the port 98 so that the pressure of the fluid discharged from the pumping unit C is increased and exerts a pressure against the control portion 108 of the spool 106 against the force of the compression spring 114 so that the spool 106 is moved to the right. Thus, a port 124 which is in communication with the passage 96 may discharge fluid across the bore 104, into a registering passage 126 and then through a longitudinally extending passage 128 to the discharge passage 122.

The control portion 90 of the spool 84 is dimensioned to afford sufficient movement of the spool to effect closing of the port 98 by the control portion 86. An addi-

tional increment of movement of the control portion 90 permits the control fluid on the right side thereof to discharge through the passage 120.

By the above-described invention, means are provided for recirculating the discharge of one pumping unit of a combination pump at relatively low pressure. By this arrangement, excessive heating and effervescing of the recirculated fuel are effectively precluded. In the present instance, the pumping unit C is activated in response to peak demand pressure of the pumping unit B so that additional fuel is provided to the afterburner during periods of peak requirement such as at takeoff or acceleration. In the present instance also, the recirculation control is located within the pump so that the distance which the recirculated fuel is pumped is minimized.

It will be understood that modifications and variations may be effected without departing from the scope of the novel concepts of the present invention.

I claim as my invention:

1. In combination, a first pump operable to discharge fuel to a burner of a reaction engine, a second pump for selectively supplying fuel to the burner in response to the discharge pressure of said first pump, and means for activating said second pump at periods of peak flow demand manifested by said discharge pressure of said first pump, said means comprising a valve assembly having a first bore, a valve spool slidably mounted therein and having longitudinally spaced control portions, a second bore communicating with said first bore, a valve spool slidably mounted in said second bore, said second-named valve spool having a plurality of longitudinally spaced control portions, said second-named valve spool being normally positioned to afford recirculation of the discharge from said second pump at relatively low pressure, said second-named valve spool being movable axially in response to an increase in pressure of the discharge from said first pump to a predetermined level to terminate the recirculation of the discharge from said second pump, said first-named valve spool being movable axially in response to an increase in pressure of the discharge from said second pump to a predetermined value to interconnect the discharge of said second pump and the discharge of said first pump to afford an increased fuel supply to said burner.

2. In a fuel system for reaction engines and the like, in combination, a first pump for supplying fuel to a burner, a second pump for selectively supplying fuel to the burner, and means operative in response to the pressure of the discharge from said first pump for activating said second pump during periods of peak fuel flow requirements, said means comprising a valve assembly having a first bore, a valve spool slidably mounted therein and having longitudinally spaced control portions, a second bore communicating with said first bore, a valve spool slidably mounted in said second bore, said second-named valve spool having a plurality of longitudinally spaced control portions, said second named valve spool being normally positioned to afford recirculation of the discharge from said second pump at relatively low pressure, said second-named valve spool being movable axially in response to an increase in pressure of the discharge from said first pump to a predetermined level to terminate the recirculation of the discharge from said second pump, said first-named valve spool being movable axially in response to an increase in pressure of the discharge from said second pump to a predetermined value to interconnect the discharge of said second pump and the discharge of said first pump to afford an increased fuel supply to said burner.

3. In a fuel system for reaction engines and the like having first and second pumps and including a valve assembly integral with said pumps and having a first bore, a valve spool slidably mounted in said bore and having a plurality of longitudinally spaced control portions normally positioned to afford free passage of the discharge from said first pump therethrough, a second bore having longitudinally spaced ports for selective communication with said first bore a bypass communicating with the second bore for recirculating the discharge from said second pump back to the inlet thereof, a valve spool slidably mounted in said second bore and having longitudinally spaced control portions normally affording free passage therethrough of the discharge from said first pump while preventing the free passage therethrough of the discharge from said second pump, said second-named spool being movable axially in response to an increase in pressure of the discharge from said first pump to a predetermined level to terminate the recirculation of the discharge from said second pump, said first-named valve spool being movable axially in response to an increase in pressure of the discharge from said second pump to a predetermined value to interconnect the discharge of said second pump and the discharge of said first pump to afford an increased fuel supply.

4. In a fuel system for reaction engines and the like having a combination pump including a first pump operable to discharge fuel to a burner of the reaction engine, a second pump for selectively supplying fuel to the burner in response to the discharge pressure of said first pump, and means for activating said second pump at periods of peak demand, said means comprising a valve assembly having a first bore, a valve spool slidably mounted therein and having longitudinally spaced control portions, a second bore communicating with said first bore, a valve spool slidably mounted in said second bore, said second-named valve spool having a plurality of longitudinally spaced control portions, said second-named valve spool being normally positioned to afford recirculation of the discharge from said second pump at a pressure substantially lower than the normal output pressure thereof, said second-named valve spool being movable axially in response to an increase in pressure of the discharge from said first pump to a predetermined level to terminate the recirculation of the discharge from said second pump, said first-named valve spool being movable axially in response to a predetermined increase in pressure of the discharge from said second pump to interconnect the discharge of said second pump and the discharge of said first pump to afford an increased fuel supply to the burner.

5. In a fuel system where the delivery pressure increases with demand, a fuel mechanism comprising in combination, a first pump for supplying fuel under pressure to the system, a fuel delivery line connected to the output from said first pump for delivering fuel, a second pump for selectively supplying fuel under pressure to the system, said second pump normally inoperative to deliver fuel under pressure, and pressure responsive pump actuating means connected to said fuel delivery line and to said second pump and operative in response to the discharge pressure from said first pump to activate said second pump upon a predetermined rise in pressure of said discharge during periods of peak fuel flow requirement to cause the second pump to deliver fuel under pressure to the system so that a saving in power for operating said pumps is effected during periods when said second pump is inoperative.

6. In a fuel system where delivery pressure increases with demand, a fuel delivery mechanism comprising in combination, a first pump having an output connected for supplying fuel to the system, the output pressure of said pump varying as a function of output flow, a second pump for selectively supplying fuel to the system, and pressure responsive pump control means connected to the output of said first pump and operative in response to the discharge pressure of said first pump for activating said second pump upon a predetermined rise in pressure of said discharge during periods of peak demand, said means comprising a valve assembly connected to the output of said second pump and to the output of said

first pump and operative in one position to by-pass the discharge from said second pump and shifting in response to said predetermined rise in pressure of the discharge of the first pump to a second position to connect the output of the first pump to the output of the second pump.

7. In a fuel system where delivery pressure increases with demand, a fuel delivery mechanism comprising in combination, a first pump for supplying fuel under pressure, a first fuel delivery line connected to the output from said first pump and connected to the system for delivering fuel, a second pump for selectively supplying fuel under pressure, a second fuel delivery line connected between the output of said second pump and said first fuel delivery line so that said first and second pumps can both deliver fuel to the system, a by-pass line connected to said second fuel delivery line for by-passing the fuel delivered from said second pump, a by-pass valve in said by-pass line, pressure responsive valve operating means connected to said by-pass valve actuated by discharge pressure of the first pump to close said by-pass valve upon a predetermined rise in fuel pressure in said first fuel delivery line, a separating valve in said second fuel delivery line between said by-pass line and said first fuel delivery line stopping fuel flow from said first delivery line to said by-pass line, and valve operating means connected to said separating valve and operative to close said separating valve when said by-pass valve is open and to open said separating valve when said by-pass valve is closed.

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