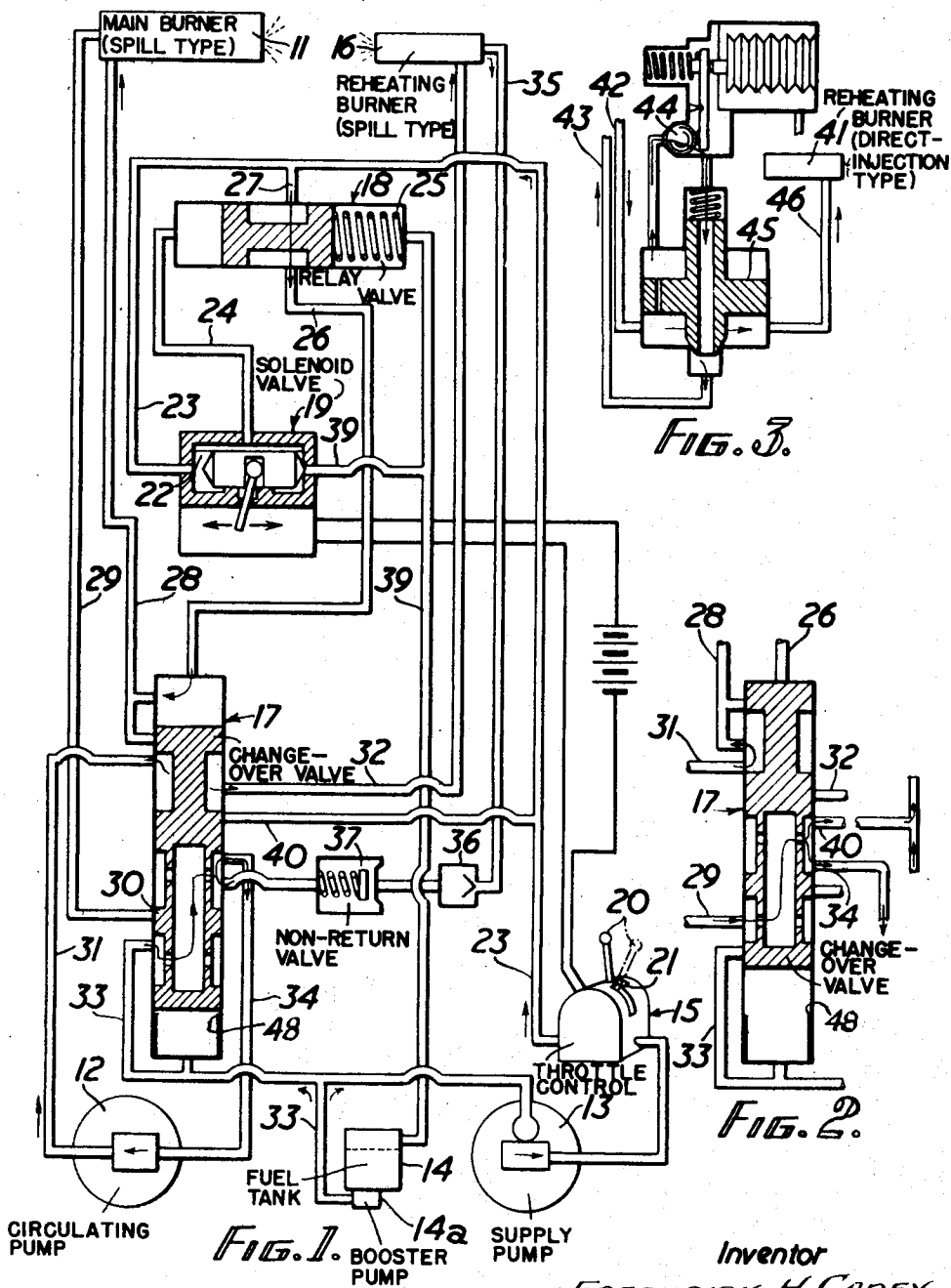


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LIQUID FUEL SUPPLY SYSTEM FOR INTERNAL-COMBUSTION
TURBINES WITH AFTERBURNERS
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LIQUID FUEL SUPPLY SYSTEM FOR
INTERNAL-COMBUSTION TURBINES
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11 Claims. (Cl. 60—35.6)

1

2

This invention relates to liquid fuel supply systems for aircraft internal combustion turbine power units. One method of boosting engine thrust is to re-heat the exhaust gases after passing through the turbine and the invention is concerned more particularly with the supply of fuel to the burners provided for effecting this re-heating. The thrust boost is generally required during take-off and may also be required under certain conditions of flight. The object of the invention is to provide for re-heating or after-burning in a system supplying main burners of the spill type and incorporating two pumps of which one serves during normal running to circulate fuel around a circuit including the swirl chambers of the burners and the other delivers into this circuit fuel in excess of the capacity of the circuit so as to cause corresponding amounts to issue through the burner orifices. Such a system forms the subject of my Patent No. 2,608,247, issued August 26, 1952. The advantage of such a system is that the pump which causes the fuel to circulate, hereinafter referred to as the circulating pump, although not by itself causing fuel to issue through the burner orifices, ensures effectual atomization of any fuel delivered into the circuit by the other pump, hereinafter referred to as the supply pump. Thus, even at low engine speeds, the fuel injected into the circuit by the supply pump is properly atomized and a sensitive control of the engine speed is obtained.

The invention makes use of the fact that the thrust boost is required only at maximum throttle openings at which the flow from the supply to meet engine requirements is sufficient to ensure satisfactory atomization and the circulating pump has lost its primary function. According to this invention, therefore, in a fuel supply system of the kind referred to and incorporating burners for re-heating the exhaust gases for the purpose of providing thrust boost, the capacity of one of the pumps, e. g. the circulating pump, is utilised when thrust boost is required in order to supply fuel to the re-heating burners while the main combustion chamber burners receive their fuel from the other pump.

When the main spill burners are being supplied with fuel from say the supply pump only, i. e. during thrust boost, the common return line from these burners may be closed, for example by means of a non-return valve, so that the burners may function as simple direct injection nozzles.

The burners of the after-burning system may themselves be either of the spill type or of the

direct-injection type, and the capacity of the pump used for feeding these burners may in some cases be supplemented by an auxiliary pump of any desired capacity.

When the circulating pump is to feed the burners of the re-heating system, the pilot may effect the necessary change in the main system by moving his engine control lever or throttle lever beyond its maximum throttle setting to bring about movement of what may be termed a change-over valve, which movement isolates the circulating pump from the main burners and places it in communication with the re-heating burners and with a source of supply of fuel. The isolation of the circulating pump from the main burners may automatically close the return line from the latter.

A fuel system in accordance with the invention will now be described by way of example with reference to the accompanying diagrammatic drawing, of which

Figure 1 shows one system with the parts in the positions they occupy during re-heating;

Figure 2 is a fragmentary view showing a detail in the position it occupies during normal engine running; and

Figure 3 is a modification.

Referring to Figures 1 and 2, the system there shown includes main burners of the spill type, one of which is shown at 11, a circulating pump 12 for circulating fuel around a circuit including the swirl chambers of the burners 11, a supply pump 13 for feeding fuel from a tank 14 through a throttle control 15 into the circulating flow set up by the pump 12, re-heating burners of the spill type (there are usually two, of which one is indicated at 16), a change-over valve 17, a relay valve 18, and a solenoid valve 19.

The change-over valve 17 has four lands and during normal engine running, i. e. when there is no supply to the re-heating burners 16, occupies the position shown in Figure 2 by virtue of pressure applied against the lower end of the valve member from the tank booster pump 14a. The electrical windings (not shown) of the solenoid valve 19 are included in an electrical circuit having a switch (not shown) housed within the throttle casing 15 and closed whenever the throttle lever 20 is moved beyond the maximum throttle setting, in the throttle opening sense which maximum setting is indicated in Figure 1 in dotted lines. When the lever 20 is moved in the throttle opening sense beyond the maximum throttle setting, through the side step 21 of the

3

throttle gate, to the full line position shown in Figure 1, the switch closes so that the solenoid coil is energized to trip the valve element of the solenoid valve 19 into the right-hand position shown in Figure 1. It will be seen that when the solenoid valve is in this position, fuel passes from the supply pump 13 through the throttle 15 to enter the valve chamber 22 by a conduit 23. From the chamber 22 the fuel passes by a conduit 24 to act upon one end of the relay valve 18 to shift the valve element against a spring 25 in order to place a conduit 26 in communication with a branch conduit 27 leading from the conduit 23. Movement of the relay valve 18 therefore permits fuel from the supply pump 13 to reach the upper end of the change-over valve 17 which shifts the latter from the normal running position shown in Figure 2 against a fixed stop 48 into the after-burning or re-heating position shown in Figure 1. The various valves will remain in this position so long as the solenoid winding is energized by the position of the throttle lever 20. In addition to acting upon the valve 17, fuel from the supply pump 13 will be fed to the main burners 11 along a conduit 28. Although the burners 11 are of the spill type they will function during the re-heating operation as direct injection nozzles on account of the return line 29 being closed by the land 30 of the change-over valve. The re-heating burners 16 receive fuel from the circulating pump 12 which feeds along a conduit 31 through a section of the change-over valve 17 and through a conduit 32. During the re-heating operation the circulating pump 12 is supplied with fuel from the tank 14 through conduits 33, through the change-over valve 17, and through a conduit 34. The return line 35 from the burners 16 communicates with the inlet of the circulating pump 12 and includes a restrictor 36 and a non-return valve 37.

As soon as the throttle lever 20 is pulled in a throttle closing sense to or beyond the maximum throttle setting indicated in dotted lines, the switch of the solenoid valve 19 will open and the solenoid valve element will move to the left under the influence of a spring to close the end of the conduit 23 and to place the conduit 24 in communication with a conduit 39 leading to the low pressure zone above the fuel in the tank 14. The relay valve 18 will thereupon move to the left by the spring 25 to place the conduits 26 and 27 in communication with the conduit 39 just referred to so that the pressure above the change-over valve 17 falls and the valve 17 rises into the position shown in Figure 2, under the influence of pressure acting on the valve's lower end, supplied from the booster pump 14a.

The booster pump 14a, being driven independently of the engine, serves at all times to prime the supply pump 13. During the reheating operation (Figure 1) the booster pump 14a primes the pump 12, also, by way of conduit 33, the lower portion of change-over valve 17, and conduit 34, although under normal running conditions (Figure 2) the pump 12, or the latter's intake side which is included within the circulating path which pump 12 keeps filled, is supplied excess fuel in controlled amounts by the supply pump 13, and so needs no supply from booster pump 14a (otherwise than indirectly via pump 13) and is not so supplied. The booster pump is of a type such that, in case it fails, it will not block supply to the pump or pumps which it primes, thus to starve it or them.

4

Normal running ensues as soon as the change-over valve 17 reaches the position shown in Figure 2. In this position the pump 12 circulates fuel around a closed and completely filled circuit including the conduit 31, the uppermost portion of the change-over valve, the conduit 28 to the swirl chamber of the main burner 11, and thence via conduit 29, and back to conduit 34 and the low-pressure side of the circulating pump by way of a second portion of the change-over valve. The supply pump continues to receive fuel from the booster pump 14a, which it delivers past throttle 15 and through conduit 23 as far as the branch conduit 40 and then into the change-over valve, in the same portion of that valve as is at the time included within the closed circulation path of the pump 12. The amount of fuel added at this point from the pump 13 to the closed conduit overfills the latter, and effects corresponding discharge at the orifice of the main spill burner 11. In other words, the supply pump now feeds to the inlet of the circulating pump. This system will continue to function for normal running for any position of the throttle lever 20 at or below the maximum throttle setting of the lever but as soon as the lever 20 is moved through the step in the gate the solenoid valve will be energized and the system will again become as shown in Figure 1 in which the main spill burners are functioning as direct injection nozzles and the re-heating burners are being supplied with fuel.

Referring now to the modification shown in Figure 3, the re-heating spill burners 16 of Figure 1 are replaced by simplex or direct injection burners 41 and in place of the restrictor 36 and the non-return valve 37 there is provided an altitude control between the conduits 32 and 35. The conduits 42 and 43 of Figure 3 can be regarded as continuations of the conduits 32 and 35 respectively of Figure 1 with the burners 16 omitted. The altitude control comprises an aneroid-controlled release valve 44 associated with a pressure-regulating by-pass valve 45. For any given altitude the pressure required to unseat the release valve 44 will be constant which will determine the constant pressure in the conduit 46 leading from the valve 45 to the burners 41. Variations in altitude will through the aneroid vary the pressure at which the release valve 44 unseats which in turn will vary the pressure in the conduit 46 correspondingly. The supply of fuel to the re-heating burners 41 will thus be regulated in accordance with altitude; it being understood that less fuel is needed with higher altitude.

An altitude control such as that shown in Figure 3 may also be provided across the conduits 32 and 35 of Figure 1 with the restrictor 36 omitted.

If it is desired to supplement the capacity of the circulating pump during re-heating, there may be provided an auxiliary pump controlled by an additional land on the change-over valve so that said auxiliary pump operates in parallel with the circulating pump during re-heating.

If the circulating system for the main burners is designed for emergency operation in accordance with co-pending United States application Serial No. 2,342, filed January 14, 1948, it is feasible to utilise the capacity of the supply pump for feeding the re-heating burners during re-heating and to use the circulating pump for feeding the main burners.

Basically the invention utilises for feeding the after-burners, one of the two pumps essential to

5

the circulating system for the main burners, and utilises such pump at a time when the other pump alone is able to ensure effective atomization of the fuel discharged by the main burners.

What I claim is:

1. A liquid-fuel supply system especially for aircraft engines, for the continuous supply of fuel to an atomizing main burner of the spill type, but which is capable of functioning as a direct injection nozzle, and for the occasional supply of fuel to an exhaust reheating burner, which system comprises a circulating pump, a supply pump, a change-over valve including a valve body shiftable between a normal-running and a reheating position, respectively, and a closed circuit including said circulating pump and said change-over valve but excluding said supply pump, said closed circuit including a supply conduit leading from the circulating pump to the change-over valve and thence adapted for connection to the main burner nozzle for supply of fuel to the burner nozzle under normal running conditions, and including also a return conduit from the main burner nozzle to the change-over valve and thence to the intake side of the circulating pump, for return of fuel to such pump under normal running conditions, a delivery conduit leading from said supply pump to a connection at said change-over valve with said closed circuit for delivery into the latter, during normal running conditions, whereby to effect corresponding discharge at the main burner nozzle, throttle means operatively connected in said delivery conduit intermediate the supply pump and said connection at the change-over valve to the closed circuit, and movable to vary the effective delivery from said supply pump between a minimum and a normal maximum limit, and on beyond in the throttle-opening sense to an abnormal maximum limit, a branch line leading from said delivery conduit, at a point beyond the throttle means from the supply pump, to a connection at the change-over valve to the main burner supply conduit, a reheating burner supply line extending from said change-over valve and adapted to be connected to the reheating burner, a low pressure connection adapted to be connected to a fuel source and extending to said supply pump and also by way of said change-over valve to a connection with the circulating pump's intake, and a reheating burner return line leading to said change-over valve, said change-over valve and its valve body being so organized and arranged that, when in the normal running position it maintains the closed circuit open for circulation of fuel from the circulating pump to the main burner nozzle and return, and the delivery conduit from the supply pump open to augment the fuel in said closed circuit, for corresponding discharge at the main spill burner, and further organized and arranged, when in its normal running position, to close the branch line connection from the supply pump to the main burner supply conduit, and to close also the reheating burner supply line and the low pressure connection to the circulating pump's intake, and the reheating burner return line, and means operatively connected to said throttle means, arranged and operable by movement of the latter past the normal limit in the throttle-opening sense, to shift said change-over valve body into its reheating position, said change-over valve being further organized and arranged that, in such reheating position, it interrupts said closed circuit and said delivery conduit, and connects the circulating

6

pump only to said reheating burner supply line for delivery to the reheating burner, and to said low pressure connection for fuel supply, and said reheating burner return line to the circulating conduit and circulating pump's intake, and being further organized and arranged to connect said supply pump only to said branch line and thence at the change-over valve to the main burner supply line for delivery to the main burner nozzle, and to close the return conduit from the main burner nozzle, said means which are operatively connected to the throttle means being operative conversely, upon movement past the normal limit in the throttle-closing sense, to shift the change-over valve back into position to restore the interrupted or altered conduits for normal running.

2. The combination of claim 1, including a fuel source and a booster pump operatively associated therewith and connected at all times to the low pressure connection and thereby to the intake of the supply pump, a low pressure branch connection from said low pressure connection to the circulating pump by way of said throttle-operated means, the latter having elements normally closing off said branch connection, but said throttle-operated means being arranged to open the low pressure branch connection automatically upon movement of the throttle means beyond the normal maximum limit, to connect the booster pump discharge into the closed conduit which at such time includes the circulating pump and the reheating burner, for spill type operation of the latter burner.

3. The combination of claim 1, wherein the throttle-operated means includes a solenoid valve yieldingly biased into a normal position, and operatively associated valve means normally held in position to close off delivery from the supply pump to the reheating burner, and electrical control means for said solenoid valve operatively connection for operation by said throttle means, arranged for energization of the solenoid and shifting of the solenoid valve and of the associated valve means controlled thereby, upon movement of said throttle means beyond the normal maximum limit in the throttle opening sense, to connect the discharge from the supply pump to the means which is operatively connected to said throttle-operated means, to shift the latter and thereby to isolate the two pumps, to close the normal return line of the circulating pump, and to supply fuel from the supply pump to the main burner nozzle, and from the circulating pump to the reheating burner nozzle.

4. The combination of claim 1, characterized in that the reheating burner is of the direct injection type, a pressure control by-pass valve in the reheating burner supply line, an aneroid-controlled release valve operatively connected to said pressure control by-pass valve, to automatically regulate supply to the reheating burner, when the latter is operative, in accordance with altitude effects.

5. In combination with a main burner of the spill type and an exhaust reheating burner of an aircraft internal combustion turbine engine, a fuel source, a circulating pump, a first conduit means for circulating fuel in a normally closed circuit which includes said main burner and said circulating pump, a supply pump, a second conduit means for circulating fuel abnormally in a closed circuit which includes said supply pump, part of said first conduit means, and said reheating burner, a change-over valve arranged in common in and including elements controlling

7

each of the two conduit means, and shiftable from a normal position wherein the supply pump is connected into the closed circuit of the circulating pump for augmentation of the supply to the main burner, and is closed off from the reheating burner, into an abnormal position wherein return from the main burner is cut off, the delivery from the circulating pump and the return thereto are connected to the reheating burner, and the delivery from the supply pump is connected to the main burner, means including a throttle lever for regulating supply of fuel from the supply pump to whichever burner is connected to the latter for supply, said throttle lever being shiftable through a normal range and also, therebeyond in the throttle-opening sense, through an abnormal range, and means operable by movement of said throttle lever into its abnormal range to shift said change-over valve into its abnormal position, or upon return of said throttle lever to its normal range to shift said change-over valve into its normal position.

6. The combination of claim 5, including a booster pump operatively associated with said fuel source, and for delivery to said supply pump and, in the abnormal position only of the change-over valve, by way of the latter to the closed circuit which then includes the circulating pump and the reheating burner, for augmentation of supply to the latter.

7. The combination of claim 5, wherein the throttle lever operable means includes a solenoid valve yieldingly biased into a normal position, and connected to the throttle lever for electrical operation upon movement of said throttle lever into its abnormal range, into an abnormal position affording connection of pressure fluid from the supply pump to the change-over valve, to initiate movement of the change-over valve into its abnormal position.

8. The combination of claim 7, including also a relay valve yieldingly biased into a normal position, and in communication with the delivery pressure from the supply pump by way of the solenoid valve upon movement of the latter into its abnormal position, to connect the supply pump delivery to the main burner.

9. In combination with a main burner of the spill type and an exhaust reheating burner of the direct injection type, of an aircraft internal combustion turbine engine, a fuel source, a circulating pump, a first conduit means for circulating fuel normally in a closed circuit which includes said main burner and said circulating pump, a supply pump, normally connected to said first conduit means to augment supply to the main burner, a second conduit means for delivering fuel abnormally from the supply pump to the main burner by way in part of the first conduit means, and from the circulating pump to the reheating burner, also by way in part of the first conduit means, a change-over valve arranged in common in and including elements controlling each of the two conduit means, and shiftable from a normal position wherein the two pumps cooperate to supply fuel to the main burner, and fuel supply to the reheating burner is cut off, to an abnormal position wherein the pumps are isolated, and supply the one the main burner and the other the reheating burner, a throttle lever shiftable through a normal range and also therebeyond in the throttle-opening sense through an abnormal range, means including said throttle lever for regulating supply of fuel from the supply pump, and operable

8

automatically upon movement of the throttle lever into its abnormal range to shift the change-over valve into its abnormal position, and an aneroid-controlled release valve in the second conduit means, and a cooperating pressure-controlled by-pass valve, to regulate supply to the reheating burner, during abnormal operation, automatically in accordance with pressure altitude.

10. A liquid fuel supply system especially for aircraft engines, for the continuous supply of fuel to an atomizing main burner nozzle of the spill type, but which is capable of functioning as a direct injection nozzle, and for the occasional supply of fuel to an exhaust reheating burner also of the spill type, which system comprises a change-over valve housing and valve body therein shiftable between a normal running position and a reheating position, supply and return conduits each extending by way of said valve housing to define, when said valve body is in normal running position, a primary closed circuit which is freely open and adapted to be connected, at a first side of the valve housing, to the main burner nozzle for delivery of fuel thereto and return of fuel therefrom, a circulating pump included in said closed circuit at a second side of the valve housing, opposite said first side, and of such capacity relative to the supply and return conduits as to maintain the circuit and the main burner nozzle substantially full to the point of overflowing without itself causing any discharge therefrom so long as the valve body is in normal running position, a supply pump located externally of said circuit and adapted to be connected to a supply source, a delivery conduit leading from said supply pump and connected by way of said valve housing for delivery into said closed circuit, when the valve body is in its normal running position, to augment the supply within the closed circuit and to effect corresponding discharge at the main burner nozzle, throttle means operatively connected in said delivery conduit and movable to vary the effective delivery from said supply pump between minimum and a normal maximum limit, and on beyond in the throttle-opening sense to an abnormal maximum limit, a reheating burner supply conduit leading from and a reheating burner return conduit leading to the valve housing, and each adapted to be connected to the reheating burner nozzle for delivery of fuel thereto and return of the fuel therefrom, and to define with that portion of the aforesaid closed circuit which is at the second side of the valve housing a secondary circuit which is closed for continuous circulation when the valve body is in its reheating position, said valve body being formed and arranged to close said secondary closed circuit and to establish said primary closed circuit, including the circulating pump, and to connect said delivery conduit to said primary closed circuit, so long as such valve body remains in normal running position, and to interrupt said primary closed circuit and to establish said secondary closed circuit when the valve body is in reheating position, a branch line leading from said delivery conduit, beyond the throttle means from the supply pump, to the main burner supply conduit by way of said valve housing, a low pressure connection adapted to be connected to a fuel supply source and extending to said valve housing, the valve body being further formed and arranged to close said branch line and said low pressure connection so long as the valve body is

9

in normal running position, and to establish communication between the branch line and the main burner supply conduit, and between the low pressure connection and said secondary closed circuit to augment the supply in the latter, for spill discharge at the reheating burner, when the valve body is in reheating position, and means operatively connected to said throttle means, for operation by movement of the latter beyond its normal maximum limit in the throttle-opening sense, to shift said valve body into its reheating position, and conversely for return of said valve body to its normal running position by return movement of the throttle means within its normal operating limits.

11. A liquid-fuel supply system as in claim 10, wherein the means operatively connected with the throttle means includes a solenoid valve in said branch line normally closed to interrupt supply by way of said branch line to the main burner supply conduit, electrical means operatively connected to said solenoid valve, and to

10

the throttle means to open the solenoid valve upon movement of the throttle means in the throttle-opening sense beyond its normal maximum limit, a relay valve biased into a closed position, means controlled by opening of said solenoid valve to open said relay valve, and a pressure line connected, past said relay valve, to said change-over valve to shift the latter automatically from its normal running position upon opening of the relay valve.

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