Sept. 4, 1951 | E. M. REDDING | 2,566,373

FUEL CONTROL SYSTEM FOR TURBOJET ENGINES

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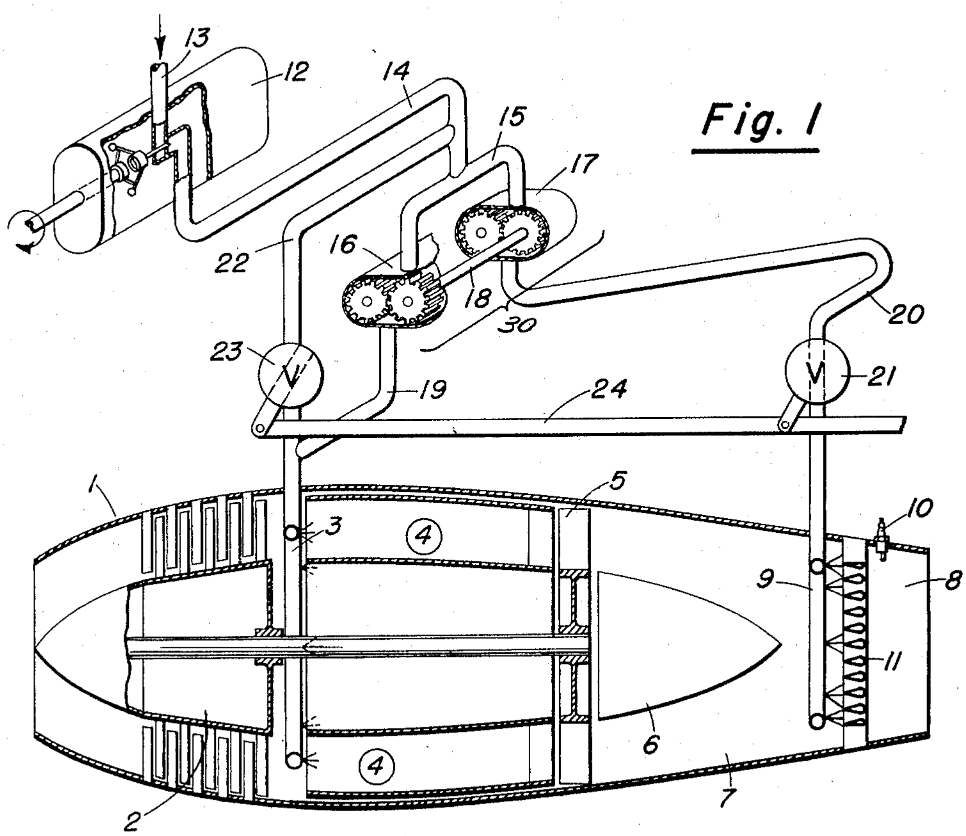

Fig. 1

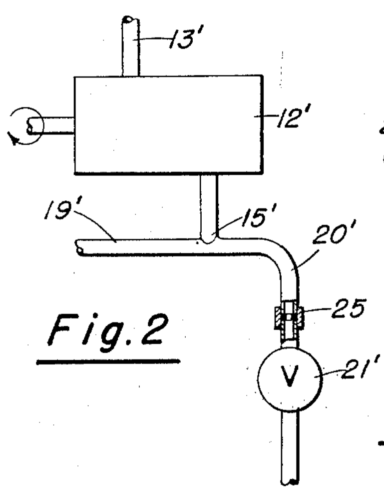

Fig. 2

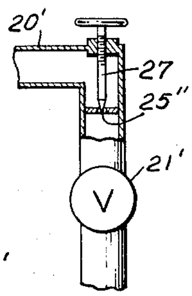

Fig. 4

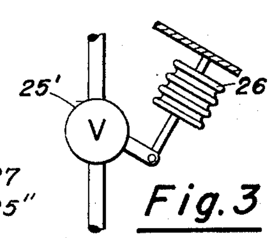

Fig. 3

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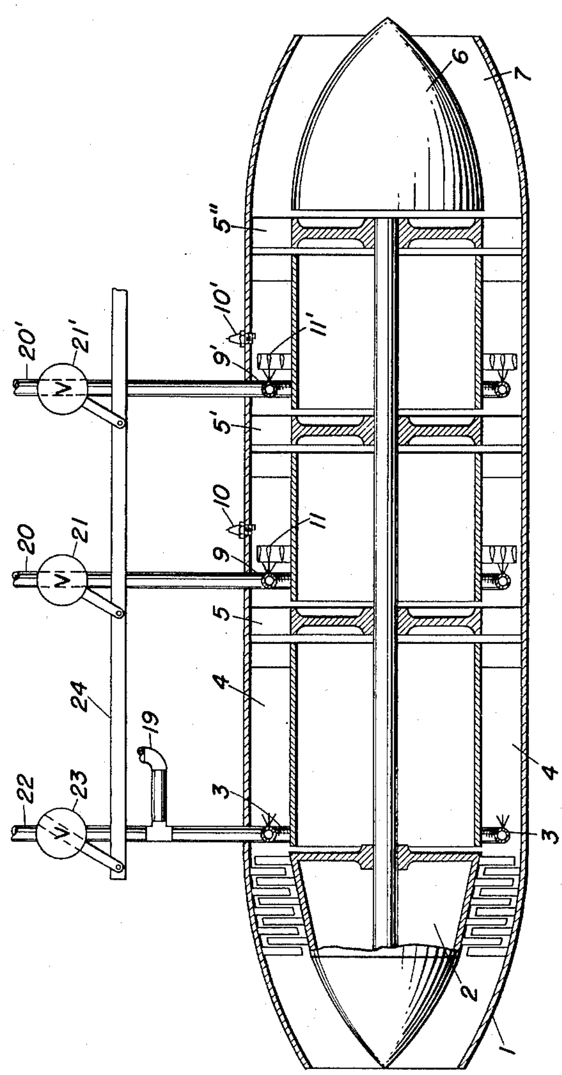
Fig. 5



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FUEL CONTROL SYSTEM FOR TURBOJET ENGINES

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7 Claims. (Cl. 60—35.6)

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This invention relates to aircraft propulsion motors of the reaction type and in particular to their fuel systems.

An object of the invention is to deliver auxiliary fuel to a reaction motor so that a desired optimum exhaust temperature may be maintained irrespective of variations in flight conditions.

Another object is to utilize a single fuel governor control to supply fuel to both the main and auxiliary fuel systems of a reaction motor so that the respective rates of flow of the latter two will be under control of the former.

Further objects, advantages and salient features of the inventions will become apparent from the following description, accompanying drawings and appended claims.

In the drawings:

Fig. 1 represents one embodiment of the invention and shows a longitudinal section of a generally conventional reaction motor together with a diagrammatic illustration of a fuel system;

Fig. 2 illustrates another embodiment of a fuel system adapted for use with the motor of Fig. 1;

Fig. 3 illustrates a modification of a portion of Fig. 2;

Fig. 4 is a similar modification, wherein the orifice is made adjustable; and

Fig. 5 illustrates a modification, wherein the arrangement shown in Fig. 1 is supplemented by additional turbine and reheat devices.

Referring to Fig. 1, 1 represents a reaction motor having a compressor 2, main fuel supply manifold 3, combustion chamber 4, gas turbine 5 and tail cone 6. Fuel delivered by the manifold is burned in the combustion chamber by air delivered from the compressor, the products of combustion passing through and driving the turbine, which in turn drives the compressor. The products of combustion then pass into exhaust pipe 7 and issue from nozzle 8 providing thrust for the unit. These features are regarded as conventional in the art.

In the exhaust pipe 7 a manifold 9 is provided which delivers fuel into the gas flow by means of a plurality of jets, its combustion raising the temperature of the exhaust gases, adding to their kinetic energy which increases the thrust of the unit over that which would be obtained by the main fuel system alone. At 10 is illustrated a suitable ignition device to initiate combustion of the fuel supplied by manifold 9 and 11 is a flame holder to maintain uniform combustion. These latter two devices are conventional in the art.

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The auxiliary system is essentially a reheat device which raises the temperature of gases previously cooled by expansion. It may function in the manner previously described, that is, to increase the thrust of the unit or may reheat the gases for subsequent use in another gas turbine stage as shown e. g. in Fig. 5. It is contemplated, accordingly, that another gas turbine 5' could be used in the gas flow downstream from the auxiliary fuel supply. It is apparent, also, and contemplated, that more than one auxiliary fuel system could be used where successive gas reheat would be advantageous as e. g., fuel manifolds 9 and 9' with flame holders 11 and 11', ignition devices 10 and 10', and the auxiliary turbines 5' and 5'', shown in Fig. 5.

The advantages, generally, of adding auxiliary fuel, as aforementioned have been recognized but systems proposed or used prior to this invention have not given optimum performance under variable flight conditions because of lack of proper control of the auxiliary fuel. It is apparent that if the auxiliary system supplies less than an optimum amount of fuel, the gas temperature in the exhaust pipe will be less than the materials are capable of withstanding and hence the highest performance of the unit will not be obtained, whereas, if more than an optimum amount of fuel is introduced the temperatures will be higher than the materials are capable of withstanding and their useful life will be materially impaired. An optimum fuel flow would be one such that the temperatures are the maximum which the materials can withstand for a certain desired useful life or that which effects an improved overall thermal cycle.

It has been found that at constant R. P. M. the exhaust pipe temperature, resulting from the addition of auxiliary fuel, can be kept substantially constant under variable flight conditions if the amount of fuel introduced into the auxiliary system bears a fixed relationship or ratio at all times to the main fuel supply. The system herein described accomplishes this desirable result.

At 12 is diagrammatically illustrated a governor which at any particular throttle setting will control the delivery of fuel to a combustion chamber at such a rate that constant turbine speed will be maintained irrespective of variations in flight speed, altitude, air temperature or pressure. This device per se does not constitute a part of the invention but it is contemplated that any governor of the foregoing general type may be used in combination with the fuel system disclosed by this invention.

The governor receives its fuel from any convenient source of supply such as a fuel tank, booster pump, and fuel pump in series, the fuel entering supply line 13. The governor discharges fuel into a single line 14 which branches by a T connection at 15, one branch thereof being connected to a metering device 16 and the other branch to metering device 17. These two devices are constructed in much the same manner as conventional gear pumps and together they constitute a proportional fuel divider 30. They are connected by a shaft 18 so that they operate in unison, but are not mechanically driven, the rotation of the gears being effected by the flow of fuel through the devices. They are so proportioned in size that their respective delivery rates are in a fixed ratio regardless of total rate of flow. Alternately, they could be made the same size and be suitably connected by gearing such that their respective rates of flow would be in proportion to their rates of rotation.

Metering device 16, which would normally be designed to deliver a smaller quantity of fuel than 17, due to the normally smaller requirements of the primary combustion chamber, is connected to the main fuel manifold 3 by line 19. The other metering device 17 is connected to the auxiliary fuel manifold 9 by line 20. A valve 21 is provided in line 20 to render the auxiliary supply inoperative when its use is not desired. A line 22 by-passes the metering device 16 and is provided with a valve 23 which is connected to valve 21 by link 24 so that the two valves operate in unison, and when valve 21 is closed, valve 23 is open. Valves 21 and 23 are not metering valves, but simple cut-off valves linked together for reverse operation. This link may, if desired, be connected to the pilot's throttle so that valves 21 and 23 are under control of the throttle only as it is moved to its full throttle position; that is, under normal power requirements only the main fuel system leading to manifold 3 would be in use but when full power is desired movement of the throttle to full open position would render the auxiliary system leading to manifold 9 operative also. Throttling is at all times controlled by adjustment of the governor 12. When 21 is closed and 23 opened, metering device 17, being of the positive displacement type will not operate. This in turn will preclude shaft 18 from rotating and render metering device 16 inoperative, the entire flow then passing through by-pass line 22.

While the metering devices above described are of the gear type, it is apparent from the teachings of the invention that other functional equivalents will suggest themselves, and could be employed, to achieve the same ultimate results. It is contemplated that all metering devices which will distribute liquid to a plurality of discharge lines in a manner to effect a constant ratio of mass flow between the respective discharge lines, are within the spirit and scope of the invention.

Fig. 2 illustrates another embodiment of a fuel system which will achieve substantially the same results as the one previously described. Primed figures represent parts corresponding to those of Fig. 1. In this embodiment the discharge line from governor 12' branches at 15' in the same manner as the other embodiment, a portion of the fuel being delivered to the main fuel system 3 by line 19' and the remaining portion to auxiliary manifold 9 by line 20'. This line is provided with a valve 21' to render the auxiliary supply inoperative, when its use is not desired, and an orifice 25 which will meter a constant proportion of the discharge of governor 12' to the auxiliary system. The ratio of flows through 19' and 20' may be adjusted for optimum exhaust temperature by the choice of a suitable orifice. The fixed orifice 25 may comprise an orifice as shown at 25'' in Fig. 4, which is adjustable by means of needle valve 27; this orifice would be so designed that its area could be adjusted by manual operation of the needle 27 during static calibration tests of the engine to maintain the proper fuel flow ratio to the main and auxiliary fuel injectors. The area so found is held constant during operation of the engine, or until further calibration tests are made at a later date.

In lieu of a fixed orifice as previously described, the orifice could be made adjustable by using an adjustable valve 25' as shown in Fig. 3 in place of the fixed orifice 25 shown in Fig. 2, or the fixed orifice 25'' shown in Fig. 4. This valve 25' could be placed under manual control of the pilot, who would make the adjustments in accordance with observed indications of the temperature at the exhaust pipe to produce and maintain a fuel flow such that a desired exhaust pipe temperature would be maintained. The use of the adjustable valve 25' under control of the pilot is for the purpose of placing the ratio of fuel flows to the two combustion stages wthin the control of the pilot during flight. The advantage of this device lies in being able to precisely regulate the temperature of the gases from the auxiliary combustion chamber to a fixed valve. When the area of the orifice is maintained constant during a flight through various altitudes at a R. P. M. of the engine, calculations show that the exhaust gas temperature would vary slightly. Adjustable valve 25' would allow the pilot to rectify this, getting an indication of the exhaust gas temperature on his instrument board from a thermocouple or a similar device in the engine exhaust pipe, neither the thermocouple or other device being here illustrated, as not a part of the invention.

As an added refinement, however, to obtain more precise temperature control the valve could be automatically controlled by a barometric device 26, as shown in Fig. 3, which would function to regulate the auxiliary flow in response to changes of air pressure which is related to the resulting changes in the exhaust pipe temperatures due to changes in altitude at constant turbine speed.

The governor 12 maintaining constant turbine R. P. M. has nothing to do with orifice 25, valve 25', and barometric device 26. The governor operates independently of the proposed metering device and any of its parts.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What I claim is:

1. A reaction motor having a first stage combustion chamber providing gases for driving a turbine, and one or more additional stage combustion chambers for additional power generation, a fuel injector for each of said chambers, a governor controlled fuel metering means for supplying fuel under pressure at a controlled rate, a distribution system between said metering means and said injectors, including a proportional fuel divider means operated in response to said fuel pressure, a supply conduit from said metering means to said divided means, a fuel de-

livery line for delivering one portion of the fuel from said divider means to the first stage fuel injector, a second fuel delivery line for delivering the remainder of the fuel from said divider means to the remaining fuel injectors, a by-pass conduit from said supply conduit to said first delivery line, cut-off means in said by-pass conduit and in said second fuel delivery line, and control means for operating said cut-off means simultaneously so that when one is open the other is closed, whereby all the fuel may be selectively delivered either directly through said by-pass conduit into said first stage injector or proportionally through said divider means and said delivery lines into said first and additional stage injectors, irrespective of the rate of the total fuel supply.

2. A reaction motor as defined in claim 1 wherein said proportional fuel divider means comprises a pair of positive displacement gear pumps having a common drive shaft and a common inlet connected to said supply conduit, the outlet of one of said gear pumps being connected to said first fuel delivery line and the outlet of said other gear pump being connected to said second fuel delivery line, whereby when the cut-off means in said by-pass conduit is closed the fuel supply will be delivered proportionally to the first and second delivery line in accordance with the relative capacities of said gear pumps, and when the cut-off means in said by-pass conduit is open, the fuel divider will not operate, but all the fuel will be delivered to said first delivery line.

3. A reaction motor as defined in claim 2 wherein the gear pump connected to said first fuel delivery line has a smaller capacity than said other gear pump, in accordance with the relatively smaller fuel requirements of the primary combustion chamber, when the fuel is being delivered through said fuel divider.

4. A reaction motor as defined in claim 1 wherein said proportional fuel divider means comprises an open passage to said first fuel delivery line, and a restricted passage to said second delivery line precalibrated to deliver the desired proportions of the fuel supplied through said delivery lines.

5. A reaction motor as defined in claim 4 wherein said restricted passage comprises a fixed restriction.

6. A reaction motor as defined in claim 4 wherein said restricted passage comprises an adjustable restriction, with means for presetting the adjustment during calibration under static tests.

7. A reaction motor as defined in claim 4 wherein said restricted passage comprises a metering valve for manual control during motor operation.

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