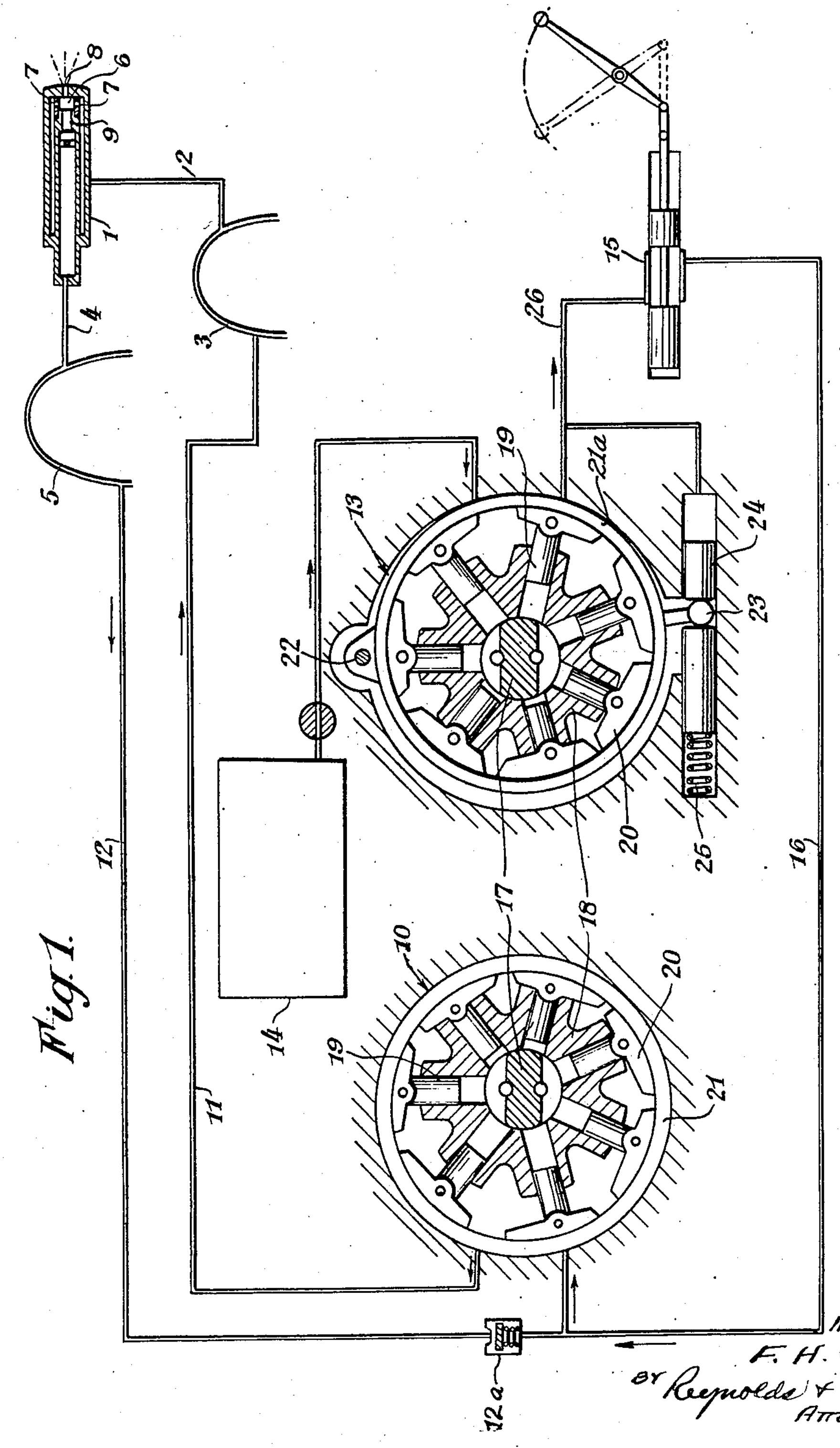
Aug. 26, 1952 F. H. CAREY 2,608,247

FUEL SUPPLY SYSTEM FOR SPILL TYPE BURNERS

Filed Jan. 14, 1948 2 SHEETS—SHEET 1



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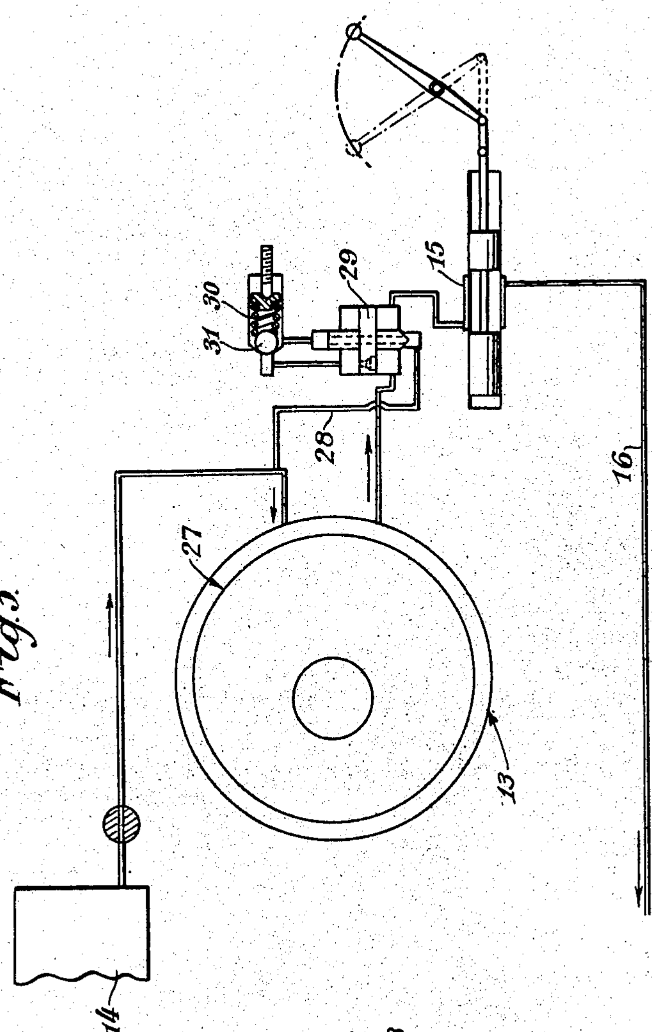

Fig. 3.

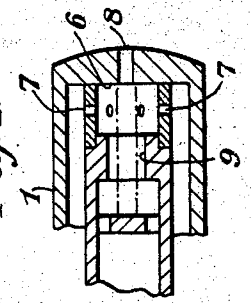

Fig. 2.

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FUEL SUPPLY SYSTEM FOR SPILL TYPE BURNERS

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6 Claims. (Cl. 158—36.4)

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The various designs of burner used in continuous combustion gas turbines may be divided into two categories of which one category comprises the more generally used burners known as simple direct-injection burner nozzles in which all the fuel supplied to the burner passes out through its discharge orifice, and the other category comprises burners in which, except during certain operating conditions, only a proportion of the fuel supplied to the burner nozzle passes out through the discharge orifice and the remainder flows back along a return line. This invention is concerned with liquid-fuel supply systems for those burner nozzles of the second mentioned category in which flow through the return orifice precedes any discharge through the discharge orifice, and for convenience all such burners or nozzles are hereinafter referred to as "spill burners as herein specified." The patents to Peabody, No. 1,628,424 and to Bargeboer No. 2,079,430 disclose examples of such burner nozzles, although the supply system of Peabody differs greatly from that herein disclosed and claimed. As at present constructed, these burner nozzles have a discharge orifice arranged as a co-axial outlet from a swirl chamber into which the fuel is supplied tangentially, the return or spill orifice being axially in line with the discharge orifice but of larger capacity so that until the return flow is retarded in some way no discharge from the discharge orifice takes place, the fuel simply swirling in the swirl chamber and passing off by the return line. The output of such burners is dependent, not on the volume of fuel circulated, nor the rate of circulation, nor yet alone or necessarily on the rate of supply of fuel, but rather on the amount by which the fuel supplied exceeds the return flow capacity of the system.

Spill burners have the inherent advantage over the simple direct-injection burners that they can produce a satisfactorily atomized spray throughout a greater flow range without necessitating unduly high pump pressures. This is an important consideration with gas turbines for aircraft propulsion, owing to the wide altitude range within which the aircraft has to fly which brings about very considerable variations in the engine fuel requirements for the same engine speed. The problem is rendered more acute by the fact that the pumps used for supplying the fuel to the burners are for various considerations more usually driven by the engine, in order to save the weight of separate pump-drive means, hence pump output varies with engine speed.

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From the point of view of fuel economy the modern tendency is for aircraft to be designed to operate at great altitude at which the engine requires considerably less fuel for the same engine speed than it would require at a low altitude. The reason why spill burners which possess this advantage are not more generally employed is because the nozzles have not hitherto been given a satisfactory environment, the supply systems hitherto associated with these nozzles being unsatisfactory particularly when relatively small quantities of fuel are being discharged from the burners, as is particularly the case at high altitudes. The known systems have been unable to cater in a satisfactory manner for maximum and minimum engine speeds at extreme altitudes.

The primary object of the present invention is to provide an improved system for supplying fuel to aircraft spill burners as herein specified, which affords a more efficient atomization of the discharged fuel and also a greater sensitivity of control. In its application to aircraft propulsion, the invention affords better atomization having in mind the considerable variations in engine fuel requirements at extreme altitudes of flight, and bearing in mind that the fuel is usually supplied by one or more pumps driven by the engine.

According to one aspect, the present invention consists in a liquid-fuel supply system for spill burners as herein specified, in which the operation of two pumps are coordinated to the desired ends. One thereof, a circulating pump, operates normally to circulate fuel in a circuit including the swirl chambers of the burner nozzles, said circulating pump being so rated in relation to the circuit that it maintains the circuit substantially at capacity without of itself causing any discharge through the nozzle discharge orifices, and the other a supply pump, operates normally, and under the influence of a manually controllable throttle means, to inject into the circulating flow a controllable flow of fuel whose presence causes the capacity of the circuit to be exceeded to cause atomized fuel to issue from the nozzle discharge orifices at a controlled rate. Also, according to the invention, a liquid-fuel supply system for an aircraft continuous combustion turbine engine having spill burners as herein specified, comprises such a circulating pump which may be driven by the engine and is operative normally to circulate fuel around a circuit including the burner nozzles, and such a supply pump which also may be driven by the engine and is operative normally to inject fuel into the circuit under control of throttle means as necessary to maintain a required engine speed or to effect any change thereof.

The supply pump may be of the variable displacement type, or of the fixed displacement type with an associated controllable by-pass. This pump may inject into the circulating flow at some point in the supply line running between the circulating pump and the burner nozzles, but it is preferred so to arrange the system that during normal running of the engine the supply pump injects into the circulating flow at a point in the return line from the nozzles to the circulating pump, wherefore, by reaction along the return line, to impede flow from the swirl chamber by way of the return line, and to effect discharge therefrom, instead, by way of the nozzle discharge orifice.

The invention will now be described by way of example with reference to the accompanying diagrammatic drawings of which:

Figure 1 shows one system embodying the invention;

Figure 2 is a fragmentary sectional view of a detail of the nozzle drawn to an enlarged scale, and

Figure 3 shows a modified pump unit and coordinate control device for the same.

In the system shown in Figures 1 and 2, fuel is supplied to a group of nozzles **1** (only one of which is shown). All the nozzles **1** have their inlets **2** connected with what is known as a burner ring **3**, namely, a fluid flow ring whence fuel flows to several nozzles, and their return lines **4** connected with what is known as a collector ring **5**, which is a similar fluid flow ring whereto unused fuel flows from the several nozzles. In the particular example shown, each nozzle has a swirl chamber **6** into which the fuel is supplied through a number of tangential passages **7** so that the incoming fuel swirls around the wall of the chamber **6** to build up what may be defined as a tube of fuel with a centrally disposed air core. At the outer end of the swirl chamber **6** the nozzle is formed with a discharge orifice **8** and at the other end of the swirl chamber with a spill orifice **9** which is coaxial with the discharge orifice **8** and of greater area. The system comprises essentially two pumps of which one, a circulating pump **10**, operates to circulate fuel around a circuit including a supply line **11**, the burner ring **3**, the swirl chambers **6** of all the nozzles **1**, the collector ring **5** and a return line **12**, wherein is a non-return valve **12*a***. The other pump, a supply pump **13**, serves to withdraw fuel from a tank **14** and to discharge it through a metering valve or throttle **15**, whereby the supply pump's effective delivery is regulated, and along a line **16** to inject the fuel into the circulating flow set up by the circulating pump **10**.

The circulating pump **10** operates as a fixed delivery pump and will usually be engine driven. The supply pump **13** is also usually driven by the engine and operates as a variable delivery pump to inject fuel into the circulating flow at a selected rate. In the example under consideration, each pump comprises a ported valve spindle **17** around which there rotates a radial cylinder assembly **18** having radially disposed reciprocating pistons **19** provided at their outer ends with slipper bearing pads **20** running against the inner surface of a track ring **21** the eccentricity of which with respect to the axis of the valve spindle **17** determines the operative strokes of the pistons. The track ring **21** of the circulating pump **10** is of fixed eccentricity with respect to the corresponding valve spindle **17**. The track ring **21*a*** of the supply pump **13** is mounted to rock about a pivot **22** so that its eccentricity with respect to its valve spindle **17** may be varied. For this purpose, the track ring has a projecting finger **23** extending intermediately of the length of a pressure loaded plunger **24** which is influenced by a spring **25** to tend to move the track ring to a position of maximum eccentricity. The plunger **24** is also exposed to the pressure in the delivery line from the pump **13** which pressure acts in the opposite sense to that of the spring **25**. By these means the pump **13** automatically takes up a position in accordance with the setting of the metering valve **15** to maintain a constant pressure in the delivery line **26** running from the pump to the metering valve.

In my burner the pressure impressed upon the fuel by the circulating pump **10** is employed only for the purpose of conveying the fuel through the supply line **11** and into the chamber **6**. Once it enters the chamber **6** its pressure is largely converted into movement, and because it enters tangentially at orifices **7** its movement is a whirling movement about the axis of the chamber. It its escape from the chamber were impeded, the chamber would fill up, but by design the return line **12** is of adequate capacity to accommodate all the fuel which the circulating pump **10** alone can deliver, and this offers no obstacle to free escape. Its first and only obstacle is the spill orifice **9**, and it fills up only until it overcomes that obstacle, whereupon it flows over the same. Since there is no other impedance to its escape, under such conditions, there is no further filling up of the chamber **6**, for instance, to the level of burner discharge orifice **8**, and the fuel merely whirls about the chamber in a "tube." If it could be assumed that all this time the supply pump **13** is running, but is in neutral, inactive, or non-delivering position, it is clear that it would not affect the results described above; actually, should the supply pump fail to deliver, the engine, hence the pumps themselves, would cease to run.

Were it possible to maintain the nozzle and its chamber **6** always horizontal, and to subject a pool of fuel which may rest therein only to gravitational force, it is evident that the fuel upon entering would collect until it rises to the level of the spill orifice **9**, but would then flow over the same, acting as a weir, and would thereafter flow back along the return line (since the latter has ample capacity to receive it if only the circulating pump is assumed to be delivering), and would never rise to a level to flow out of the nozzle's discharge orifice **8**. But, if the return line **12** be overloaded beyond its capacity, as by inlet thereto beyond the nozzle, or if additional fuel be supplied to the supply line by way of the supply pump **13**—either such possibility being within the contemplation of this invention—the fuel spilling over the weir at **9** could not escape as fast as it enters the chamber **6**, wherefore it would rise, until eventually it discharges at the orifice **8**, until initial conditions are restored.

But it is not possible to maintain the nozzle and its chamber **6** always horizontal, and always subject only to gravitational force. The nozzle's attitude or orientation with relation to the horizontal, and the forces acting upon a pool of fuel which might rest therein, are transcient and variable, and dependent upon the attitude of the aircraft and the forces, centrifugal, gravitational, etc. acting upon the latter. It follows that simple spilling from the nozzle, as a purely gravitational effect, is undependable. The "pool" of fuel must be replaced by the "tube" of fuel already alluded to, which follows as a result of the tangential whirling of the fuel about the axis of the chamber 6, and this locally centrifugally induced tube is freed of the gravitational and centrifugal forces acting upon the aircraft as a whole, so that it maintains its attitude and orientation with respect to the nozzle, the spill orifice 9, and the nozzle's discharge orifice 8, while at the same time acting in all other respects as did the theoretical pool discussed above.

So long as the capacity of the return line 12 is not exceeded, fuel will spill out at 9 before it can rise to discharge at 8. So long as the return line 12 can not accommodate the fuel spilling out at 9, it will accumulate in the chamber 6, until it "rises" sufficiently to discharge at 8. By so regulating the amount of fuel permitted to accumulate in the chamber 6, the amount thereof discharged at 8 is subject to control to a very fine degree.

The circulating pump 10 is so rated in relation to the design of the burners 1 and to the supply and return lines 11 and 12 that in operation it maintains around the circuit a sufficient rate of flow to maintain the circuit and the swirl chambers of all the burners substantially full without of itself causing any fuel to issue through the nozzle's discharge orifices 8. That is to say the circulating pump will maintain "tubes" of fuel within the swirl chambers of all nozzles of thickness consistent with no discharge through the discharge orifices, as illustrated purely diagrammatically in Figure 2. In this condition any fuel injected into the circulating flow by the supply pump 13 will result in corresponding discharges from the nozzles, and the rate of swirl within the nozzles will ensure effectual atomization of the discharged fuel however small the quantities discharged may be. This is of very great importance when the system forms part of an aircraft continuous combustion turbine engine, owing to the fact that the aircraft will have to operate over a wide altitude range with consequential variations in the engine fuel requirements for the same R. P. M. of the engine.

In Figure 3 there is illustrated a modification of the variable delivery supply pump 13 of Figure 1. The pump 13 in this case is replaced by a variable delivery unit comprising a pump 27 of the fixed displacement type and an associated by-pass 28 extending between the inlet and outlet of the pump. The quantity of fuel permitted to flow along the by-pass 28 is controlled by a relief valve 29 which in turn may be controlled by the setting of a spring 30 on a valve 31. The relief valve 29 is a well known expedient for maintaining a constant or maximum pressure in a fluid flow line.

A further example of spill burners of this general type is disclosed in Peabody British Patent No. 380,117, of September 9, 1932, and an example of the same general type of fuel supply system, incorporating spill burners, is disclosed in Rover British Patent No. 608,576, of August 8, 1942, accepted September 17, 1948. The Rover system is designed for terrestrial use, where atmospheric pressure differences are negligible, and do not appreciably affect engine speeds, and the type of speed control disclosed therein renders the system ill-suited for use in aircraft, at altitudes varying widely, and particularly at extreme upper altitudes where continuous combustion turbine engines, with which the present invention is concerned, are most effective, but require delicate controls.

It will be appreciated that various modifications may be made without departing from the invention, for example spill burners of different constructions as already alluded to may be used; other types of pump may be employed; and also the supply pump, as in the Rover patent, Figure 2, may inject into the circulating flow in the supply line between the circulating pump and the nozzles instead of into the return line from the nozzles to the circulating pump as shown in the drawings. Also the system may be amplified to include various refinements such as speed governors (see Serial No. 62,636, filed November 30, 1948, now Patent No. 2,559,938, issued July 10, 1951), altitude controls (Serial No. 766,003, filed August 4, 1947), and other forms of direct or indirect throttle control. Again, the system may include means whereby the system may be modified so that the pumps serve other functions during "starting" (Serial No. 36,011, filed June 30, 1948) or "stopping" (Serial No. 2,341, filed January 14, 1948, now Patent No. 2,530,649, issued November 21, 1950) conditions of the system or in emergencies (Serial No. 2,342, filed January 14, 1948).

I claim:

1. A liquid-fuel supply system especially for aircraft engines, for supplying fuel to atomizing burner nozzles of the spill type, which system comprises supply and return conduits defining a closed circuit freely open and adapted to be connected to said burner nozzles for delivery of fuel thereto and return of fuel therefrom, a circulating pump of the fixed stroke type adapted to be driven from the aircraft engine, included in said circuit and of such capacity relative to the supply and return conduits, respectively, as to maintain the circuit and the burner nozzles substantially full to the point of overflowing without itself causing any discharge therefrom, a supply pump of the variable delivery type also adapted to be driven from the aircraft engine, located externally of said circuit, a delivery conduit leading from said supply pump and connected for delivery thence into said closed circuit, and throttle means operatively connected to said supply pump to vary the effective delivery of fuel by way of said delivery conduit from zero to a maximum, to inject into the closed circuit a controllable excess flow of fuel to effect discharge from the burner nozzles at a rate corresponding to the rate of excess flow so injected by the supply pump.

2. A liquid-fuel supply system especially for an aircraft continuous combustion turbine engine, for supplying fuel to atomizing burner nozzles of the spill type, which system comprises supply and return conduits defining a closed circuit freely open and adapted to be connected to said burner nozzles for delivery of fuel thereto and return of fuel therefrom, a circulating pump of the fixed-stroke type adapted to be driven from the engine, and included in said closed circuit and of such capacity relative to the supply and return conduits, respectively, as to maintain the circuit and the burner nozzles substantially full to the point of overflowing without

itself effecting discharge from the burner nozzles, a supply pump of the variable-delivery type also adapted to be driven from the engine, and located externally of said closed circuit, a delivery conduit leading from said supply pump and connected into said return conduit of the closed circuit for delivery of fuel into the latter, and of a capacity so to deliver at a rate such that, when added as excess to the fuel circulating in but not discharging from the closed circuit it will effect discharge at the burner nozzles, to maintain a maximum engine speed, and a manually operable throttle means interposed in said delivery conduit, and variable to regulate the rate of fuel supply from the supply pump to the closed circuit, and hence to the burner nozzles.

3. A liquid-fuel supply system as in claim 2, including automatic pressure-sensitive control means operatively connected to the delivery conduit in advance of the throttle means, and to the supply pump to vary the delivery therefrom, said control means being arranged for automatic operation under the influence of the changes in pressure in said delivery conduit to vary the effective delivery of the supply pump correspondingly, to maintain its output pressure constant.

4. A liquid-fuel supply system as in claim 2, wherein the variable-delivery supply pump is of the variable displacement type and automatic pressure-sensitive control means operatively connected to the delivery conduit in advance of the throttle means, and to the supply pump to vary said supply pump's displacement, said control means being arranged for automatic operation under the influence of changes in pressure in the delivery conduit to vary the effective delivery of the supply pump correspondingly, and thereby to maintain its output pressure constant.

5. A liquid-fuel supply system as in claim 2, wherein the system includes additionally controllable pressure-sensitive by-pass means operatively connected to the delivery conduit, to be subject to the output pressure of the supply pump as affected by varying the setting of the throttle means, and also connected to the input side of the supply pump, and automatically operable by variations in pressure in the delivery conduit to by-pass a portion of the delivered fuel to the input side of said supply pump and thereby to maintain the output pressure constant at the throttle means.

6. A liquid-fuel supply system for an engine of the continuous combustion turbine type for air-

craft propulsion, and hence subject to variations in air-fuel ratio with change of altitude, and including spill-type burner nozzles, said system comprising closed conduit means adapted to be connected to the burner nozzles for supply of fuel thereto and its return therefrom, a circulating pump of the fixed-stroke type adapted to be driven from the engine, and connected in said closed conduit means, normally operative to circulate fuel therethrough at a rate which corresponds to the engine's speed, and of a capacity, relative to said closed conduit means, less than sufficient to effect, by itself, at any altitude or engine speed, discharge of fuel at the burner nozzles, a supply pump of the variable-delivery type adapted to be driven from the engine, and located externally of but connected for discharge into said closed conduit means, to supplement the fuel circulating therein at a rate of flow which, at any given altitude, would correspond to the discharge at the burner nozzle and hence to the engine's speed, means operatively connected to said supply pump for automatic control thereof, and to the delivery therefrom, and sensitive to variations in the delivery pressure, to regulate the actual delivery from said supply pump to maintain its delivery pressure substantially constant at a given altitude, regardless of changes in engine speed, and means operable under control to regulate the amount of fuel discharged into said closed conduit means from the supply pump, and hence the engine speed at all altitudes.

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