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ENGINE FUEL FEED DEVICE

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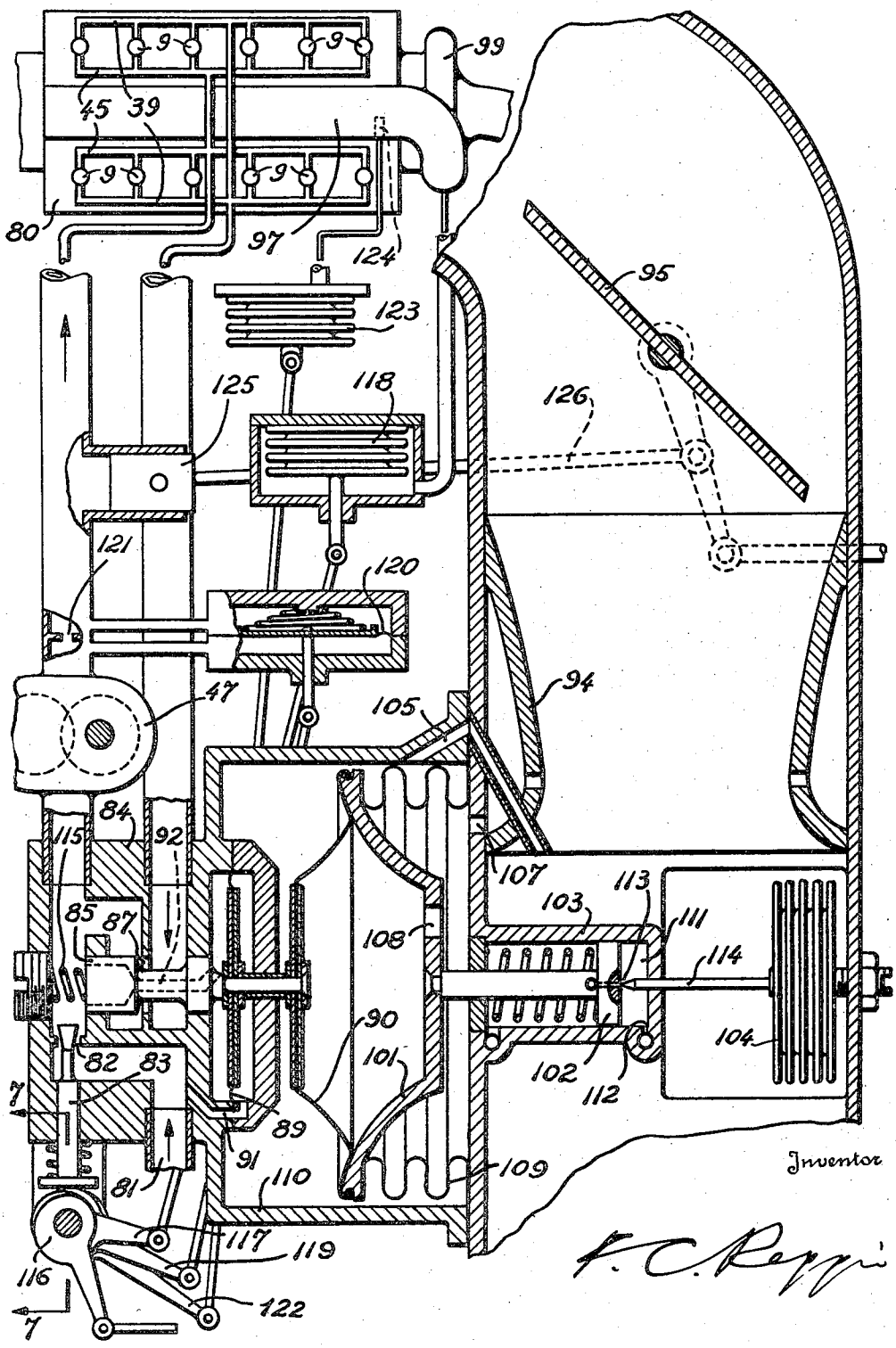

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ENGINE FUEL FEED DEVICE

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3 Claims. (Cl. 123—119)

This invention relates to fluid flow regulating systems and more particularly to fuel metering and control systems for combustion engines, this application being a division of applicant's co-pending application Serial No. 508,897 filed November 4, 1943, for Fuel Supply System.

The invention is particularly adapted for aircraft propulsion powerplants operating under varying conditions of barometric pressure, ambient temperature, thrust and speed.

An object of the invention is to provide an improved engine fuel control which automatically and under all operating conditions whether steady or transient maintains the ratio between engine fuel flow and engine air flow within predetermined upper and lower limits.

Another object is to provide an improved engine fuel control which automatically so regulates the fuel feed as to secure at all times proper combustion mixtures and maintain the temperatures resulting from combustion within desired safe limits.

The above and other objects will be apparent as the description proceeds. In the following description and in the claims various details will be identified by specific names for convenience, but they are intended to be as generic in the application as the art will permit.

The drawing, which shows an example of embodiment of the invention, is a sectional elevational view of a fuel metering device and diagrammatically indicates the connections thereof with the engine and the fuel nozzle valves.

In the specific embodiment of the invention which is here described, the engine **80** is shown as an internal combustion engine provided with an air induction system comprising a passage having an orifice or venturi **94** therein, a valve **95** and an engine-driven compressor **99** delivering air under pressure to a manifold **97** connected with the cylinder inlet ports leading to the combustion chambers.

The fuel system comprises an engine-driven fuel pump **47** which is supplied with liquid fuel at suitable pressure from a conduit **81** through an orifice **82** whose effective area is controlled by a slide valve **83**. The pump discharges fuel, always in excess of engine requirements, to the supply manifolds **45**.

A number of fuel injectors **9** are provided, each having an intake port connected with one of the fuel supply manifolds **45**, a nozzle valve through which fuel is delivered to the engine in quantity variable with the fuel pressure, and a return port in free communication with the inlet port and connected with one of the return manifolds **39** through which the excess fuel is circulated back to the inlet side of the pump **47**, as described hereinafter. These fuel injectors or nozzle units **9** are no part of the present invention. One suitable type thereof, designed for intermittently discharging fuel into the engine cylinders is described and claimed in applicant's Patent No. 2,516,828, issued July 25, 1950. Another suitable type of injector or nozzle, well known in the art, consists essentially of a

calibrated orifice through which a continuous spray of fuel is injected into the air stream in the engine air induction system or manifold.

The excess fuel which flows from the injection units **9** to the return manifolds **39** is led to a pressure regulating device or by-pass device **84** having a slidable valve **85** which controls a flow restricting orifice **87** through which the excess fuel flows back to the intake side of the pump **47**, downstream of the orifice **82**. The fuel flow through the latter orifice is thus equal to the engine fuel flow.

The valve **85** is actuated by two pressure responsive diaphragms **89** and **90**. By means of conduits **91** and **92** the fuel pressure upstream and downstream of the orifice **82** is brought to bear on opposite sides of the former diaphragm, thus applying to the valve **85** an axial load which increases with the engine fuel supply, in a direction to increase the effective area of the orifice **87**.

The flexible diaphragm **90**, connected at its center with the valve **85**, has a cup-shaped outer portion whose periphery is secured to a co-operating cup-shaped member **101** connected with the resiliently loaded piston **102** of a hydraulic servo motor **103** controlled by a venturi air density responsive bellows **104**. By means of a conduit **105** and passages **107** and **108** the venturi differential pressure is brought to bear on opposite sides of the diaphragm **90**, thus transmitting to the valve **85** a load which increases with the venturi air flow and tends to shift the valve in a direction to decrease the open area of the pressure regulating orifice **87**. A bellows **109** connected with the cup member **101** serves to define higher and lower air pressure chambers within the diaphragm housing. The cup-member **101** and the diaphragm **90** are so designed that as the former slides toward the latter, an increasing annular outer portion of the diaphragm is caused by the air pressure differential to come into contact with the member **101**, thereby decreasing the diaphragm area which is effective as pressure responsive means for the actuation of the valve **85**. The effective diaphragm area is thus variably adjustable and is dependent upon the position of the piston **102**.

Fluid under pressure, for example lubricating oil from the engine, continuously flows into the cylinder chamber **111** through a small flow restricting orifice **112**. This oil leaves the cylinder chamber through another orifice **113** formed in the piston **102** and controlled by a needle valve **114** connected to the bellows **104**. Thus the piston constantly follows the needle **114** at definite distance therefrom without exerting any reaction on the bellows **104**; when the latter contracts, the open area of orifice **113** increases, the oil pressure in chamber **111** drops, and the piston spring plus the differential air pressure on member **101** move the piston **102** toward the bellows. Conversely, when the latter expands, the effective area of orifice **113** decreases, and the increasing oil pressure in chamber **111** moves the piston away from the bellows.

The bellows **104** contains a definite mass of air or gas, and the walls thereof are so highly flexible as to expand or contract within the designed limits under negligible load. This bellows is surrounded by induction air in the immediate vicinity of the venturi, the air within the bellows thus being at the same pressure and temperature as the air flowing through the venturi, and therefore having the same density. As a result, the volume and in turn the length of the bellows are inversely proportional to the venturi air density.

The mass air flow per second W through the venturi may be calculated by the following formula

$$W=K\sqrt{\delta I}$$

where δ is the venturi air density and I is the venturi

pressure differential. In the above formula and in the following ones K represents various constants dependent upon the geometrical unchanging dimensions of the metering elements and, in some of the formulae, also upon the fuel density.

The load P applied to the valve **85** by the diaphragm **90** is

$$P=KD^2I=KD^2\frac{W^2}{\delta}$$

wherein D is the effective diameter of the diaphragm, that is, the diameter of the portion thereof which is not in contact with the cup-member **101**.

On the other hand the fuel flow per second w through the orifice **82** is

$$w=Ks\sqrt{i}$$

where s is the variable effective area of the orifice **82**, and i is the fuel pressure drop across the orifice. The load transmitted to the valve **85** by the diaphragm **89** is

$$p=Ki=K\frac{w^2}{s^2}$$

The valve **85** is subject to the light load of an idling spring **115** adjustable by means of a threaded cap. However, when the engine operates at normal speed this spring load is negligible with respect to the loads p and P. Furthermore, under the oppositely directed loads p and P the valve is in equilibrium. Substituting the relation $p=P$ in the above equations we obtain the following expression for the engine fuel-air ratio

$$\frac{w}{W}=Ks\frac{D}{\sqrt{\delta}}$$

The diaphragm **90** and the cup member **101** are so designed that as the venturi air density varies and the bellows **104** expands or contracts and shifts the cup member, the effective diameter of the diaphragm varies proportionally to the square root of the air density, thus rendering the fraction $D/\sqrt{\delta}$ constant. The fuel-air ratio then becomes $w/W=Ks$, in other words this ratio is determined by the adjustment of the needle valve **83** exclusively, irrespective of changes of altitude within the designed limits.

The profile of the cup member **101** and diaphragm **90** may readily be designed to satisfy the above requirement. If the axial length of the bellows **104** when subject to standard sea level air density is L, and the corresponding predetermined effective diameter of the diaphragm is d, at high altitude where the venturi air density is one half of the standard sea level value the length of the bellows is 2L, and owing to the changed position of the cup member relative to the diaphragm, the effective diameter of the latter will have to be 0.707 d. At higher altitude where the venturi air density is one fourth of the standard sea level value, the length of the bellows is 4L, and the effective diameter of the diaphragm will be 0.5 d.

Manual as well as automatic control of the valve **83** may be provided to regulate the engine fuel-air ratio. Four cams are shown in the drawing for actuating this valve. The cam **116** is manually controlled by means of suitable linkage means. Cam **117** is connected to a manifold air pressure responsive bellows **118**. Cam **119** is actuated in dependence upon the engine speed by a resiliently loaded diaphragm **120** responsive to the fuel pressure drop determined by an orifice **121** provided on the discharge side of the volumetric engine-driven pump **47**, and cam **122** is actuated by a bellows **123** connected with an element **124** responsive to the manifold air temperature and preferably also responsive in predetermined degree to the engine cylinder temperature. The number, character and arrangement of the automatic devices connected with the fuel-air ratio control valve **83** may of course be varied to suit specific characteristics of various types of engines.

In operation, the fuel discharged under pressure by the pump **47** is led through the supply manifolds **45** to the various injectors **9**; part of it is delivered to the engine, and the excess returns to the inlet port of the pump **47** through the return manifolds **39** and the by-pass orifice **87** controlled by the valve **85**. When the valve **85** is set in its extreme left position, with the by-pass orifice **87** fully open, no appreciable amount of pressure is set up on the discharge side of the pump **47** or within the injectors **9**, and the latter therefore do not deliver any fuel to the engine; the fuel discharged by the pump **47** is all returned to the inlet port thereof, no new fuel is admitted from the tank through the inlet pipe **81**, and therefore no pressure drop is set up across the restriction **82** controlled by the valve **83**. On the other hand, when the same valve **85** is in its extreme right position, reducing to a minimum the open area of the orifice **87**, the pressure of the fuel on the discharge side of the pump **47** and in the injectors **9** attains its maximum value, the injectors **9** deliver to the engine their maximum designed fuel flow, and the flow of fuel from the tank through the restriction **82**, and therefore the pressure drop across said restriction, attain their maximum value. It is thus clear that the valve **85** variably controls the pressure drop or pressure head across the restriction **82**.

As already stated, the diaphragm **90** exerts on the valve **85** a load which is a measure of engine air flow; and any variation in the venturi differential pressure or in the pressure and/or temperature of the air surrounding the bellows **104** actuates the valve **85** to alter the pressure head across the restriction **82**. Since any change in the speed of the engine is accompanied by a corresponding variation in engine air flow, it follows that any variation in engine speed will cause operation of the valve **85**.

These embodiments of the invention have been shown merely for purpose of illustration and not as a limitation of the scope of the invention. It is therefore to be expressly understood that the invention is not limited to the specific embodiment shown, but may be used in various other ways, in connection with other types of prime movers, that various modifications may be made to suit different requirements, and that other changes, substitutions, additions and omissions may be made in the construction, arrangement and manner of operations of the parts without departing from the limits or scope of the invention as defined in the following claims.

In interpreting the claims, where they are directed to less than all of the elements of the complete systems disclosed, they are intended to cover possible uses of the recited elements in installations which lack the non-recited elements.

I claim:

1. In a fuel control system for an engine having a combustion chamber and a compressor for supplying air to said combustion chamber, a fuel nozzle for discharging fuel under pressure into said combustion chamber, a conduit for conducting fuel to said nozzle, and fuel flow control means in said conduit including a metering restriction, a metering valve controlling the area of said restriction, an independent fuel pressure differential responsive regulator valve controlling the metering head across said restriction, and means responsive to a pressure generated by the compressor and operatively connected to said metering valve for varying the flow of fuel through said restriction as a function of said generated pressure.

2. In a fuel control system for an engine having a combustion chamber and a compressor supplying air for combustion, a fuel nozzle for discharging fuel under pressure into said combustion chamber, a conduit for conducting fuel to said nozzle, and fuel flow control means in said conduit including a metering restriction, a metering valve controlling the area of said restriction, an independent fuel pressure differential responsive regulator valve controlling the metering head across said restriction, and means responsive to absolute pressure generated by the

compressor and operatively connected to said metering valve for varying the flow of fuel through said restriction as a function of said absolute pressure.

3. In a fuel control system for an engine having a combustion chamber and a compressor for supplying air to said combustion chamber, a fuel nozzle for discharging fuel under pressure into said combustion chamber, a conduit for conducting fuel to said nozzle, a fuel pump arranged to pressurize the fuel in said conduit, and fuel flow control means in said conduit including a metering restriction, a metering valve controlling the area of said restriction, an independent fuel pressure differential responsive regulator mechanism controlling the metering head across said restriction, said mechanism including a regulator valve arranged to by-pass fuel from the high pressure side to the low pressure side of said pump and means for subjecting the regulator valve to a differential pressure varying with the metering head across said restriction, and means responsive to a pressure generated by the compressor and operatively connected to said metering valve for varying the flow of fuel through said restriction as a function of said generated pressure.

No references cited.