Feb. 10, 1953 I. H. EDELFELT ET AL 2,627,718

FUEL METERING SYSTEM

Filed March 17, 1948

Fig. 1.

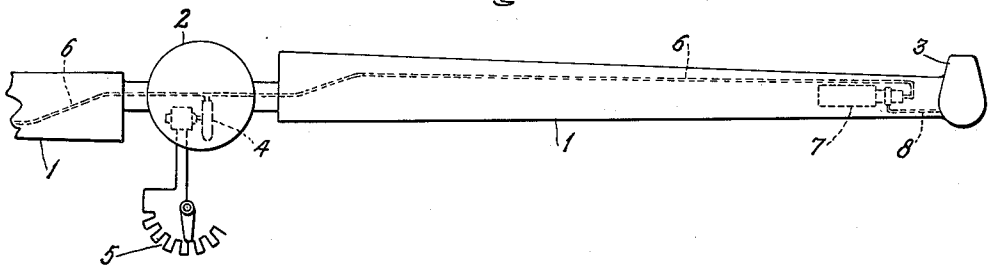


Fig. 2.

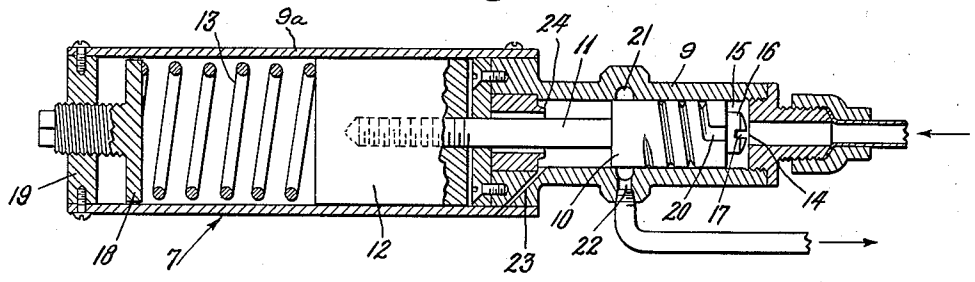
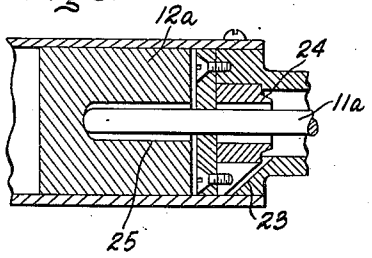


Fig. 3.



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FUEL METERING SYSTEM

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5 Claims. (Cl. 60—39.35)

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Our invention relates to a fuel metering system and more particularly to a fuel metering system of the type utilized to supply a controlled amount of fuel to a reaction motor carried on the tip of a helicopter rotor blade.

In supplying fuel to a reaction motor located at the tip of a rotating blade, a problem arises in that the fuel that is carried in the fuel line running from the hub of the rotor to the tip of the rotor blade does not flow evenly because after the fuel has proceeded a short distance through the fuel line, the centrifugal force on the fuel is great enough to cause it to break away from the rest of the fuel column. This causes intermittent fuel feeding to the combustion chamber and result in too much fuel one instant and too little, or none, the next instant. Since in this fuel metering system a fuel pressure operated control valve is located adjacent the reaction motor, a further problem arises in that during operation large pressure due to centrifugal force, in addition to the fuel pump pressure, is being impressed upon the valve. It is pointed out that quite often the pressure due to centrifugal force is much greater than that supplied by the fuel pump and yet it is necessary that the fuel pressure operated control valve be only responsive to fuel pump pressure.

Thus, one of the objects of this invention is to provide some fuel metering system to eliminate the fuel surging and breaking away of fuel in the fuel line due to centrifugal force and to eliminate the effects of such surging upon the feed of fuel to the combustion chamber.

Another object of the invention is to provide a fuel metering system valve which is solely responsive to the fuel pump pressure regardless of what the centrifugal force is, even though the pressure due to the centrifugal force is much greater than the fuel pump pressure.

Further objects and advantages of our invention will become apparent as the following description proceeds and the features of novelty which characterize our invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

In the drawing,

Fig. 1 shows a reaction motor powered helicopter rotor having a fuel metering system embodying our invention.

Fig. 2 is a cross sectional view showing constructional details of the fuel metering valve shown diagrammatically in Fig. 1.

Fig. 3 shows a modification of the structure shown in Fig. 2.

Referring to Fig. 1 of the drawing, we have

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shown diagrammatically a jet powered helicopter rotor comprising a lifting blade extending from a hub 2 and carrying, adjacent its outer tip, reaction motor 3. Mounted substantially concentrically with the center of rotation of the rotor assembly is a fuel pump 4, whose output is controlled by a suitable control 5 which is operated by the pilot. The fuel pump 4 is manifolded to fuel supply lines 6 and delivers fuel at varying pressures. The fuel supply line 6 is carried within the lifting blade 1 and runs the length of said blade towards the tip to fuel valve 7 which is mounted adjacent the reaction motor 3 substantially in the position indicated. Connected to the outlet of the fuel valve 7, is a fuel conduit 8 leading to the combustion chamber of reaction motor 3.

Referring to Fig. 2 of the drawing, which is a cross sectional view of fuel valve 7 shown in Fig. 1, we have shown the valve as comprising a valve barrel 9 and a valve barrel extension 9a. Lying within the valve barrel 9 and its extension 9a is a weighted valving piece consisting of a fuel flow governing piece 10 which cooperates in action with mass 12 through rod 11. In Fig. 2, rod 11 is shown threaded to mass 12. Due to possible difficulty in aligning parts 10 and 12, an alternative construction shown in Fig. 3 is suggested. Here rod 11a, corresponding to rod 11 of Fig. 2, fits loosely in shaft 25 in part 12a, corresponding to part 12. The bottom of shaft or recess 25, as well as the corresponding end of rod 11a, are spherically shaped to provide a bearing surface. Rod 11a coopearting with part 12a aligns parts 10 and 12a. It is pointed out that rod 11 may be part of piece 10 turned down to size or a construction similar to that described above may be used to align parts 10 and 11. Mass 12 is selected of such size that the total mass of the valving piece is in accordance with the theory set forth in another section of this specification. Also lying within the valve barrel extension 9a is a spring 13 which cooperates with the valving piece through the mass 12 to bias the fuel flow governing piece 10 so that no fuel flow results. It is important that at no time should valving piece 10 butt up against fuel inlet orifice 14 so as to prevent the fuel pressure due to centrifugal force from being exerted in chamber 15. To insure this, nipple 16 mounted on valving piece 10 has in its head a groove or grooves 17 for communicating the fuel to chamber 15 in case nipple 16 is butted up against fuel inlet 14. Spring 13 is also in contact with a back plate 18 the position of which may be radially adjusted, as back plate 18 is threaded to cooperate with threads in

member 18. By adjusting the back plate 18, the restoring force in spring 13 may be varied.

The fuel flow governing piece 10 has in its surface a helically arranged passageway or groove 20 of variable cross sectional area which in the normal position does not pass fuel, but which when in alignment with an internal circumferential recess 21 connected to valve outlet 22, does pass fuel. The valve barrel 9 has a slot 23 for draining any fluid that seeps past member 10 and a shoulder 24 that acts as a limit stop for movement of member 10. Shoulder 24 also acts to catch and direct to slot 23 any fuel that seeps past member 10 and is thrown out along the wall due to centrifugal force.

In operation, the fuel pump 4 provides the amount of fuel required at pressure, which pressure is impressed upon the fuel all along the fuel line to the valve 7 where the fuel pump pressure operates the valve which opens to permit fuel flow. When the rotor is rotating the fuel in the fuel line is also being rotated about the center of rotation and now the fuel in the fuel line is subjected to an additional pressure caused by the centrifugal forces of the fuel itself. The pressure due to this force increases as one moves toward the tip of the rotor blade and reaches a maximum at the tip of said blade. Thus at any point in the fuel line the pressure is equal to the sum of the pressures caused by centrifugal force plus that supplied by the fuel pump. It is desirable, however, that the fuel valve respond only to the fuel pump pressure. To accomplish this object, the valving piece in the valve is built of such mass that its centrifugal force is equal to the centrifugal force of the column of fuel in the fuel line. Then, since the fuel valve is unresponsive to centrifugal force, the fuel line is effectively closed at the tip and the object of eliminating surging and break away of fuel in the fuel line is accomplished because the fuel line is filled at all times. In operation, the only unbalanced force is that supplied by the fuel pump pressure and when that is applied the valving piece moves against the spring until a position is reached where the spring pressure equals the fuel pump pressure which is adjustable for control purposes. The passageway 20 is then in communication with recess 21 and fuel flows, and now the fuel is volumetrically metered by the cross sectional area of said passageway. The cross sectional area of passageway 20 is so designed that it permits the correct volumetric flow to pass as the fuel pump pressure is varied and the valving piece compresses the spring a proportional amount. Thus member 10 is solely responsive to fuel pump pressure and acts as a pressure regulated fuel metering device.

The theory upon which the valving piece design is founded is as follows: Assume the rotor blade is rotating at some speed ω. Call the length of the column of fluid from the center of rotation to the valve inlet l and let r be the distance from the center of rotation of the rotor to the centroid of the valving piece. Further assume that $r=l$, that is the centroid of the valving piece coincides with the center line of the valve fuel inlet. (This latter assumption is solely for simplicity of derivation.) Also, let the mass of the fluid be ρ_f/foot and the mass of the valving piece be ρ_v. Then, for any given ω, the force exerted by the column of fluid at the valve inlet is

$$F=\int_0^l \rho_f/\text{foot}\cdot\omega^2 x\,dx=\omega^2\rho_f\frac{l^2}{2}$$

But $\rho_f\cdot l$=the total weight of the fluid in the fuel line, and

$$\frac{l}{2}$$

is the centroid of the fuel line. Now, the force that the valving piece will exert on the fluid is, for the same ω,

$$F=\rho_v\cdot r\cdot\omega^2$$

In order that the two forces be equal we have

$$\rho_v\cdot r\cdot\omega^2=(\rho_f/\text{foot}\cdot l)\cdot\frac{l}{2}\cdot\omega^2$$

Or, expressed in words, the mass of the valving piece times the distance of its centroid from the center of rotation must equal the mass of the fluid column times the distance of its centroid from the center of rotation.

Since for any given design or configuration, of fuel system, the variables, l, ρ_f, and r, are readily determinable, it becomes possible to calculate what the mass of the valving piece should be. Obviously the valving piece may be so constructed that its total mass may be conveniently varied so as to be easily adaptable to a variety of fuel system configurations.

It will be readily apparent to one skilled in the art that the valving piece described can alternately be broken into equivalent cooperating components comprising a radially movable specific mass actuating through some means, such as a bell crank, lever, wire, spring, etc., a fuel porting system in combination with a fuel metering means, such as a shaped needle valve and port, a gate valve, a sleeve valve or other valving means suitable for metering fluid volumetrically.

Thus, while we have illustrated and described a particular embodiment of our invention, modifications thereof will occur to those skilled in the art. We desire it to be understood, therefore, that our invention is not to be limited to the particular arrangement disclosed, and we intend in the appended claims to cover all modifications which do not depart from the spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A fuel metering system for a reaction motor mounted on a rotor powered thereby comprising a fuel pump having an adjustable output pressure, a fuel line interconnecting said motor and said pump, said fuel line extending radially outward along said rotor so that due to rotation of said rotor the fuel pressure therein is affected by both the fuel pump pressure and the centrifugal force acting on the fuel therein, a fuel pressure responsive control valve interposed in said fuel line adjacent said motor for metering fuel thereto, said control valve having inlet and outlet connections, a valving piece for regulating the flow between the said connections, said valving piece being radially movable and having a predetermined mass of such magnitude that when the rotor is in operation, the centrifugal force of said valving piece is equal and opposite to the centrifugal force of the fuel column, a radially movable means cooperating with said valving piece to bias it in a closing direction, and means responsive to the fuel pump pressure for actuating said valving piece in an opening direction.

2. A fuel metering system for a reaction motor mounted on a rotor powered thereby comprising a fuel pump having an adjustable output pressure, a fuel line interconnecting said motor and said pump, said fuel line extending radially out-

ward along said rotor so that due to rotation of said rotor the fuel pressure therein is affected by both the fuel pump pressure and the centrifugal force acting on the fuel therein, a fuel pressure responsive control valve containing a valving piece interposed in said fuel line adjacent said motor for metering fuel thereto, said valving piece being radially movable and having a predetermined mass of such magnitude that when rotor is in operation, the centrifugal force of said valving piece is equal and opposite to the centrifugal force of the fuel column, and means responsive to the fuel pump pressure for metering the fuel flow.

3. In a fuel metering system for a reaction motor, said system being subjected to centrifugal force, a fuel pump, a fuel line connecting said fuel pump and said reaction motor, and a control valve located in said fuel line adjacent said motor, said control valve containing a radially movable valving piece responsive to centrifugal force to reduce the flow of fuel, the centrifugal force acting upon said fuel opposing the motion of said valve whereby the effect of centrifugal force on the rate of fuel flow is nullified.

4. A fuel metering system for a reaction motor mounted on a rotor powered thereby comprising a fuel pump having an adjustable output pressure, a fuel line interconnecting said motor and said pump, said fuel line extending radially outward along said rotor so that due to rotation of said rotor and fuel pressure therein is affected by both the fuel pump pressure and the centrifugal force acting on the fuel therein, a fuel control valve interposed in said fuel line adjacent said motor for metering fuel thereto, said fuel control valve containing a radially movable predetermined mass of such magnitude and so positioned with respect to the incoming fuel that said predetermined mass impresses upon said incoming fuel a force equal and opposite to the centrifugal force of the fuel itself, said fuel control valve containing a valving piece cooperating with said movable predetermined mass, means for biasing the valving piece to normally restrict flow, and means for volumetrically metering the fuel flow.

5. A fuel metering system for a reaction motor mounted on a rotor powered thereby comprising a fuel pump having an adjustable output pressure, a fuel line interconnecting said motor and said pump, said fuel line extending radially outward along said rotor so that due to rotation of said rotor the fuel pressure therein is affected by both the fuel pump pressure and the centrifugal force acting on the fuel therein, a fuel pressure responsive control valve interposed in said fuel line adjacent said motor for metering fuel thereto, said control valve having inlet and outlet connections, a valving piece for regulating the volumetric flow between the said connections, said valve containing a radially movable predetermined mass of such magnitude and so positioned that said predetermined mass impresses upon the fuel entering the valve a force equal and opposite to the centrifugal force of the fuel itself, and means responsive to the fuel pump pressure for actuating said valving piece in an opening direction.

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