Oct. 22, 1968 H. C. SIMMONS 3,406,910

FUEL INJECTION NOZZLE

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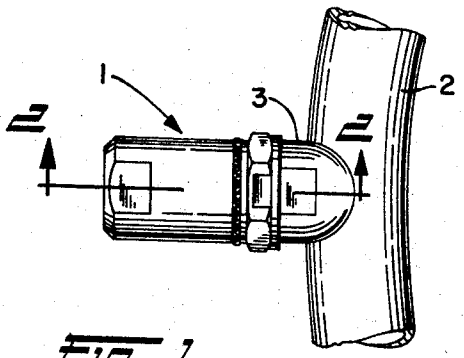


Fig. 1

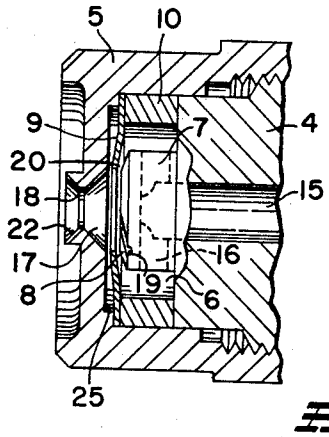


Fig. 4

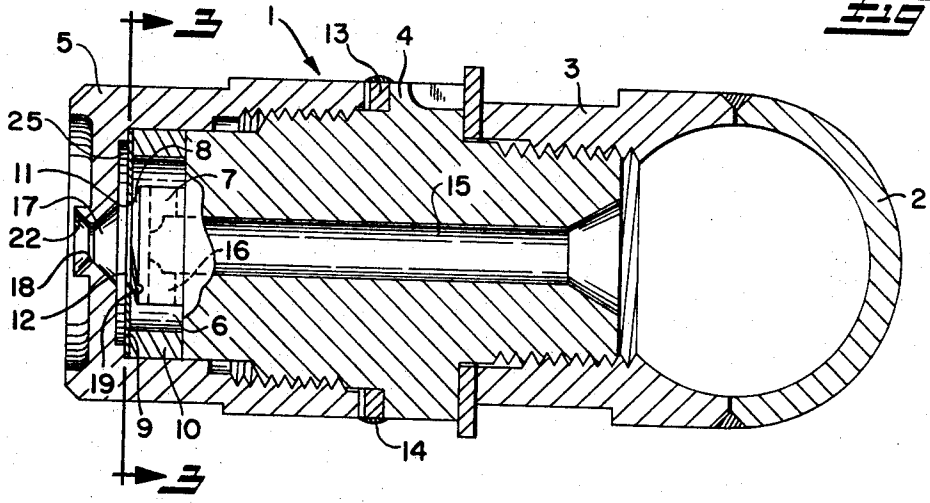


Fig. 2

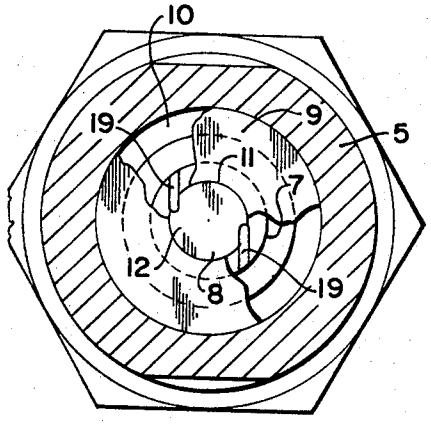


Fig. 3

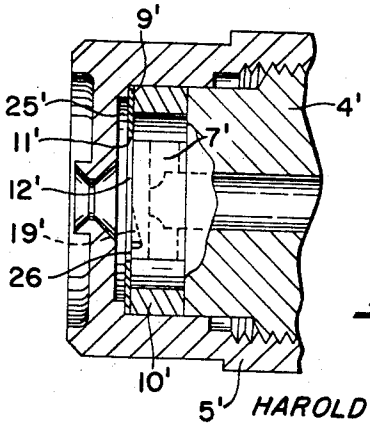


Fig. 5

INVENTOR
HAROLD C. SIMMONS

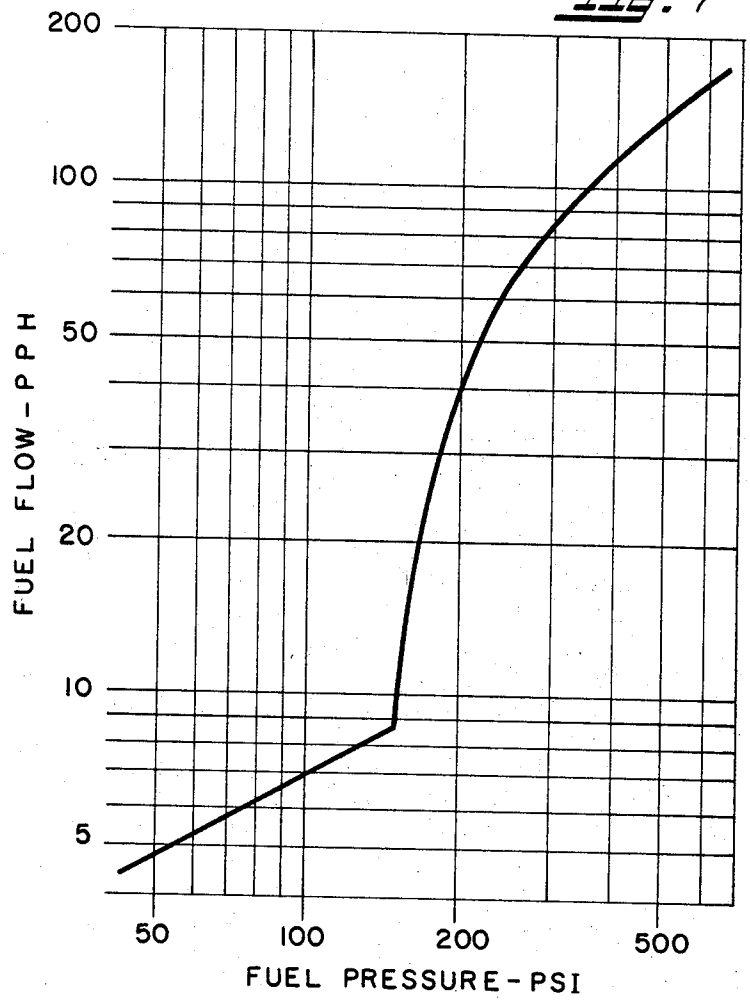
BY Oberlin, Maky & Donnelly
ATTORNEYS

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Fig. 7



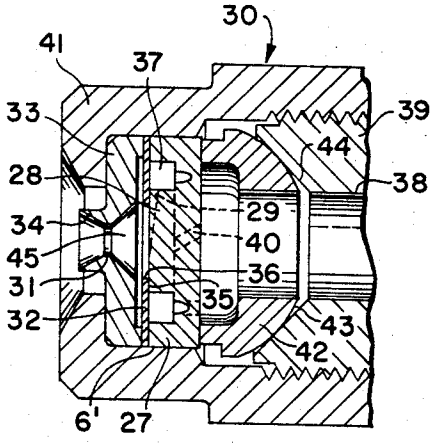


Fig. 6

INVENTOR
HAROLD C. SIMMONS

BY Oberlin, Maky & Donnelly
ATTORNEYS

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FUEL INJECTION NOZZLE

Harold C. Simmons, Richmond Heights, Ohio, assignor to Parker-Hannifin Corporation, Cleveland, Ohio, a corporation of Ohio

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ABSTRACT OF THE DISCLOSURE

A fuel injection nozzle containing a flexible diaphragm responsive to increasing pressures in a fuel chamber to permit increased flow of fuel from the fuel chamber to a spin chamber, a plurality of tangential slots permitting a continuous flow of fuel from the fuel chamber into the spin chamber regardless of the position of the flexible diaphragm thus imparting a swirling motion to the fluid in the spin chamber, and a restricted orifice through which the fuel is discharged from the spin chamber.

Disclosure

This invention relates generally, as indicated, to a fuel injection nozzle and, more particularly, to certain improvements in fuel injection nozzles of the variable area type especially suited for supplying fuel to jet afterburners or duct burners.

In present day afterburners for turbojet and ram jet engines of aircraft, the fuel flow required at each metering point may vary for example from under ten pounds per hour minimum to over 150 pounds per hour maximum, representing a flow range of at least 15:1, while the minimum fuel pressure desired is in the order of 150 p.s.i. and the maximum available is approximately 650 p.s.i., a pressure range of little more than 4:1. There are several different known types of variable area orifice nozzles which when precisely constructed are capable of delivering such a wide range of fuel flow within the indicated pressure range for most applications, including the most commonly used dual-orifice nozzle with an integral flow-dividing valve, the pintle type nozzle in which the exit orifice is varied in size directly by the valving action of the pintle, and valving means for varying the area of inlet passages either to single or dual spin chambers, but the friction which develops between the moving parts thereof due to carbonaceous deposits or the like from fuel at high operating temperatures makes them unreliable for use in supplying fuel to afterburners or duct burners. Besides that, such nozzles are rather complex and costly to manufacture, and several hunderd may be required for a single engine.

Nozzles incorporating bellows or diaphragms to vary the exit orifice area in response to variations in pressure have also been used in the past, but with poor reliability, primarily due to exposure of the diaphragms to the full nozzle pressure drop which often resulted in failure of the diaphragms and a consequent large increase in fuel flow.

It is therefore a principal object of this invention to provide a relatively simple and inexpensive fuel injection nozzle capable of effectively supplying a wide range of fuel flow to a jet afterburner or the like over a relatively narrow pressure range.

Another object is to provide such a fuel injection nozzle with no sliding parts to introduce friction, whereby the reliability of the nozzle is greatly enhanced.

Still another object is to provide such a fuel injection nozzle with a deformable diaphragm for producing automatically a change in the effective flow area of the nozzle in response to changes in fuel pressure and including a stop to prevent overstressing of the diaphragm.

A further object is to provide such a fuel injection

nozzle with an exit orifice downstream of the diaphragm, whereby the diaphragm is subjected only to a portion of the total nozzle pressure drop thus substantially reducing the chances of failure due to variations in pressure, and even if failure should occur, the increase in fuel flow will not exceed approximately 50 percent.

Another object is to provide a fuel injection nozzle of the type indicated with primary flow slots in addition to the flexible diaphragm for permitting fuel flow at low pressures with the diaphragm seated, such slots being tangential to impart a swirling motion to the fuel as it enters a common spin chamber through both the slots and diaphragm.

Other objects and advantages of the present invention will become apparent as the following description proceeds.

To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawing setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principles of the invention may be employed.

In such drawing:

FIG. 1 is a side elevation view of a preferred form of fuel injection nozzle in accordance with this invention shown connected to a spray ring manifold or the like;

FIG. 2 is an enlarged longitudinal section of the nozzle of FIG. 1 taken on the plane of the line **2—2** thereof;

FIG. 3 is a transverse section partially broken away taken on the plane of the line **3—3** of FIG. 2 to show the location of the flexible diaphragm and swirl slots;

FIG. 4 is a partial longitudinal section of the left end of the nozzle of FIG. 3, but showing the diaphragm in the flexed condition;

FIG. 5 is a partial longitudinal section showing a modified form of diaphragm seat;

FIG. 6 is a partial longitudinal section of another form of fuel injection nozzle in accordance with this invention; and

FIG. 7 is a typical flow versus pressure chart for the various nozzles of the present invention.

Turning now to the details of the various forms of fuel injection nozzles illustrated by way of example in the drawing, and first of all to the FIGS. 1–4 form, such fuel injection nozzle is generally indicated at **1** shown connected to a spray ring manifold **2** as by means of a suitable adapter **3** for metering of fuel into an afterburner or duct burner, for example. While only one such fuel injection nozzle **1** is illustrated, it should be understood that several hunderd nozzles may be required in a spraying system for a single engine.

The fuel injection nozzle **1** generally consists of a body portion **4** of a corrosion and heat resistant steel alloy, one end of which is preferably threaded to the adapter **3** for connection to the manifold **2** as aforesaid, and the other or outer end of which has a cap **5** also of a corrosion and heat resistant steel alloy threaded thereon. Between the cap **5** and body portion **4** there is an annular chamber **6** for receipt of a conical extension **7** from the body portion **4** which provides a conical seat **8** for a thin flexible disc-shaped diaphragm **9** of spring steel or the like disposed within such annular chamber **6**. The diaphragm **9** is preferably firmly gripped at its outer periphery by a ring-shaped spacer **10** within the annular chamber **6** and the cap **5** upon tightening of the cap **5** on the body portion **4** with the edge **11** of the central aperture **12** in the diaphragm **9** engaging the conical seat **8** so as to provide circular line contact therebetween. A satisfactory fuel seal may be established between the mating surfaces of the cap **5**, diaphragm **9**, spacer **10**, and body **4**. How-

ever, a weld ring **13** may be provided between the adjacent surfaces of the cap **5** and body **4** and the cap **5** welded all the way around to the body **4** as indicated at **14** in FIG. 2 to provide an additional seal, if desired.

The length of the spacer **10** may be selected so that when the cap **5** is properly tightened on the body portion **4**, the diaphragm **9** is slightly deformed against its seat **8** to preload the diaphragm, whereby a seal will be maintained between the diaphragm **9** and seat **8** until a predetermined fuel pressure within the annular chamber **6** is reached, which is desirably between 150 and 200 p.s.i.

As evident, the amount of preload on the diaphragm **9** may be varied by using spacers **10** of different lengths. Alternatively, such diaphragm preload may be varied a smaller amount by varying the extent to which the cap **5** is tightened.

Fuel is supplied to the annular chamber **6** from the manifold **2** through a central passage **15** in the body portion **4** and radial passages **16** in the conical extension **7**, from which the fuel passes into a spin chamber **17** in the cap **5** upon deflection of the diaphragm **9** away from its seat **8** and out through an exit orifice **18** into the afterburner, not shown. However, until the pressure within the annular chamber **6** is sufficient to deflect the diaphragm **9** as aforesaid, the flow will only be through a pair of tangential slots **19** provided in the conical seat **8**. This is the "primary" phase of operation of the fuel injection nozzle **1**, during which the nozzle **1** operates as a single orifice nozzle, commonly referred to as a "simplex" nozzle. Then, as the pressure in the annular chamber **6** reaches the diaphragm "cracking point," the diaphragm **9** will lift progressively away from its seat **8** to provide an annular orifice area **20** for additional fuel flow which varies automatically with changes in fuel pressure.

Because the primary slots **19** are tangential, a swirling motion is imparted to the fuel passing therethrough into the spin chamber **17** so that upon leaving the orifice **18**, the fuel is broken up into fine droplets and spread out in conical spray form by the spray deflecting lip **22** which in this case has an included angle of approximately 90 degrees. Moreover, although the annular orifice area **20** does not swirl the fuel as it passes therethrough, it has been found that the fuel passing through the primary slots **19** imparts sufficient tangential velocity to the secondary or main flow through the annular orifice area **20** to sustain free vortex flow in the common spin chamber **17**, even when the total flow is as much as eight times the flow at the same pressure through the primary slots **19** alone.

In the preferred form shown, there is a shallow counterbore **25** in the cap **5** adjacent the diaphragm **9** on the downstream side which constitutes a part of the spin chamber **17** and acts as a stop to limit the extent to which the diaphragm **9** may be deflected to reduce substantially the possibility of diaphragm failure due to overstressing. In addition, the location of the diaphragm **9** between the primary slots **19** and exit orifice **18** closely adjacent the slots **19** subjects the diaphragm **9** only to a portion of the total fuel nozzle pressure drop, corresponding essentially to the static pressure drop across the primary slots **19**. This varies somewhere between 15 percent and 25 percent of the total nozzle pressure drop, whereby the chances of diaphragm failure are yet further reduced. However, even should there be a complete failure of the diaphragm **9**, the capacity of the exit orifice **18** is preferably such that there will only be an increase of total nozzle flow not exceeding approximately 50 percent.

Although the diaphragm **9** of the FIGS. 1–4 embodiment is shown under preload engaging the conical seat **8** to establish line sealing contact therewith at low fuel pressures during the primary phase of operation of the nozzle **1**, it is generally not considered desirable to prestress the diaphragm if the operating temperatures are quite high; i.e., about 1800° F. with no fuel flow. Accordingly, especially for high temperature applications the forward end **26** of the body extension **7'** may be made flat with the tangential slots **19'** formed in the flat end surface **26** and the edge **11'** of the central aperture **12'** in the diaphragm **9'** closely spaced from or lightly contacting such forward end at low fuel pressures as in the FIG. **5** embodiment so as to eliminate diaphragm prestress. Alternatively, the extension **7** or **7'** may be eliminated altogether and a separate swirl plate **27** having a flat end face **28** with tangential slots **29** therein may be disposed in the annular chamber **6'**, as in the FIG. 6 embodiment. Accordingly, the same fuel injection nozzle **30** may be used for supplying different primary flow rates, it only being necessary to replace one swirl plate **27** with another having tangential slots **29** of different capacities. Moreover, the exit orifice **31** downstream of the diaphragm **32** may also be provided in a separate orifice plate **33**, rather than formed directly in the cap **41**, to permit ready replacement by a plate **33** having different sized exit orifices **31** or different angled deflecting lips **34** therein, as desired.

Referring further to FIG. 6, the diaphragm **32** is firmly gripped at its outer periphery between the swirl plate **27** and orifice plate **33** with the inner surface **35** of such diaphragm **32** adjacent the central aperture **36** therein engaging the flat end face **28** of the swirl plate **27**, but preferably under little or no preload. Adjacent the inner surface of the diaphragm **32** in the swirl plate **27** there is provided an annular ring-shaped chamber **37** into which the fuel flows from the manifold **2** (see FIG. 2) via a central passage **38** in the body portion **39** of the nozzle **30** and holes **40** in the swirl plate **27** prior to passing through the tangential slots **29** and the annular orifice area which is formed when the diaphragm **32** is deflected away from its seat **28**. The swirl plate holes **40** may be disposed at an angle as shown to create a swirling motion in the fuel as it enters the swirl plate chamber **37** so that the primary fuel flow will already have some tangential velocity as it enters the common spin chamber **45** and need not receive all of its swirling motion from the fuel passing through the primary slots **29**, as in the FIGS. 1–4 embodiment.

To compensate for any slight misalignment which may be present between the surfaces on the cap **41** and body portion **39** which engage the orifice plate **33** and swirl plate **27**, there is provided a stop **42** between the swirl plate **27** and body portion **39** which is in the form of a ball joint provided with a spherical surface **43** for engaging a conical socket **44** in the body portion **39**. This permits uniform clamping pressure to be applied on the diaphragm **32**, whereby erratic action of the diaphragm and leakage therearound are substantially eliminated. Otherwise, the construction and operation of the nozzle **30** of the FIG. 6 embodiment is substantially the same as those nozzles shown in FIGS. 2 and 5, and accordingly, no further reference will be made thereto.

In operation, it is preferred that the preloading of the diaphragm **9** of FIGS. 1–4 be such that the diaphragm remains seated until the fuel pressure reaches approximately 150 p.s.i. Below this pressure, the nozzle **1** functions as a simplex nozzle with flow through the primary slots **19** only as aforesaid. However, at 150 p.s.i. fuel pressure and above, the diaphragm **9** is lifted away from its seat to permit the secondary fuel flow to the spin chamber **17** which increases progressively with increasing fuel pressure, and a swirling motion is imparted to the secondary flow by the primary flow. A typical pressure versus flow curve for a nozzle constructed in accordance with FIGS. 1–4 is illustrated in FIG. 7. However, considerable variation in the shape of such curve is possible by varying such factors as the exit orifice **18** diameter, spin chamber dimensions, diaphragm **9** spring rate, diaphragm preload, diaphragm hole size, cone angle of the seat **8**, and size of the primary slots **19**. Moreover, the spray cone angle may be controlled by varying within wide limits the external lip **22** configuration of the exit orifice **18**.

From the above discussion, it can now be seen that the various forms of fuel injection nozzles disclosed here-

in are of a relatively simple construction and have no sliding parts, whereby the carbon deposits from the fuel at high operating temperatures will not interfere with the valve operation. A flexible diaphragm provides an increasing area flow nozzle with increased fuel pressure, and there is an exit orifice downstream of the diaphragm, not only to reduce the fuel pressure drop across the diaphragm, but to limit the increase of total nozzle flow to a safe level in the event of diaphragm failure.

Other modes of applying the principles of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

I therefore, particularly point out and distinctly claim as my invention:

1. A fuel injection nozzle comprising a body having an inlet for fuel under pressure and a fuel chamber in communication with said inlet, flexible diaphragm means operative in response to increasing pressure in said fuel chamber to provide an increasing annular orifice area for flow of fuel from said fuel chamber, an exit orifice in said body downstream of said diaphragm means through which the fuel from said fuel chamber flows, whereby said diaphragm means is subjected only to a portion of the total fuel nozzle pressure drop, passage means for communicating said fuel chamber with said exit orifice regardless of the position of said diaphragm means, and a spin chamber downstream of said diaphragm means and passage means into which the fuel from said fuel chamber flows, said passage means comprising a plurality of tangentially disposed slots operative to impart a swirling motion to the fuel passing therethrough sufficient to sustain free vortex flow in said spin chamber even when the flow through said annular orifice area is great.

2. A fuel injection nozzle comprising a body having an inlet for fuel under pressure and a fuel chamber in communication with said inlet, flexible diaphragm means operative in response to increasing pressure in said fuel chamber to provide an increasing annular orifice area for flow of fuel from said fuel chamber, an exit orifice in said body downstream of said diaphragm means through which the fuel from said fuel chamber flows, whereby said diaphragm means is subjected only to a portion of the total fuel nozzle pressure drop, passage means for communicating said fuel chamber with said exit orifice regardless of the position of said diaphragm means, and a removable swirl plate in said body containing said passage means, thereby permitting the use of swirl plates having different sized passage means therein, said removable swirl plate having a seat for engagement by said flexible diaphragm means at low fuel pressures, and said fuel chamber being formed in said removable swirl plate in communication with said passage means and inlet.

3. The nozzle of claim 2 wherein additional passages are provided in said removable swirl plate for communicating said fuel chamber with said inlet, said additional passages being disposed at an angle to create a swirling motion in the fuel as it enters said fuel chamber, whereby the fuel passing through said annular orifice area will have some tangential velocity.

4. The nozzle of claim 2 further comprising a removable orifice plate in said body downstream of said diaphragm means containing said exit orifice, whereby said orifice plate may be replaced with another having any desired size of exit orifice, and stop means are provided between said swirl plate and body having a spherical surface engaging a conical socket in said body to compensate

for any misalignment that might be present, whereby erratic action of said diaphragm and leakage therearound are substantially eliminated.

5. A fuel injection nozzle comprising a body having an inlet for fuel under pressure and a fuel chamber in communication with said inlet, flexible diaphragm means operative in response to increasing pressure in said fuel chamber to provide an increasing flow of fuel from said fuel chamber, an enlarged spin chamber downstream of said diaphragm means for receipt of the fuel flowing from said fuel chamber past said diaphragm means, passage means for supplying a continuous flow of fuel from said fuel chamber to said spin chamber regardless of the position of said diaphragm means, said passage means being operative to impart a swirling motion to the fluid passing therethrough to impart a swirling motion to all of the fuel in said spin chamber, and means for providing a restricted discharge of fuel from said spin chamber, whereby said diaphragm means is subjected only to a portion of the total fuel nozzle pressure drop.

6. The nozzle of claim 5 further comprising stop means in said body for limiting the amount of flexing of said diaphragm means to provide such increasing flow of fuel past said diaphragm means in response to increasing pressure in said fuel chamber as aforesaid.

7. The nozzle of claim 5 wherein said body has a central extension projecting into said fuel chamber and said flexible diaphragm means has a central aperture therethrough which defines an increasing annular orifice area with said central extension for increased flow of fuel from said fuel chamber to said spin chamber, said central extension having a conical end surface which provides a conical seat for said diaphragm means at low fuel pressures in said fuel chamber, and said passage means comprising tangential slots in said conical end surface communicating said fuel chamber with said central aperture in said diaphragm means regardless of the position of said diaphragm means.

8. The nozzle of claim 5 wherein said body has a central extension projecting into said fuel chamber and said flexible diaphragm means has a central aperture therethrough which defines an increasing annular orifice area with said central extension for increased flow of fuel from said fuel chamber to said spin chamber, the edge of said central aperture in said diaphragm means being closely radially spaced from the outer periphery of said central extension for minimum flow therebetween at low fuel pressures in said fuel chamber, said passage means comprising tangential slots in said central extension communicating said fuel chamber with said central aperture in said diaphragm means regardless of the position of said diaphragm means.

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M. HENSON WOOD, JR., *Primary Examiner.*

V. C. WILKS, *Assistant Examiner.*