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UNIT FUEL INJECTOR WITH FLUID INJECTION VALVE SPRING

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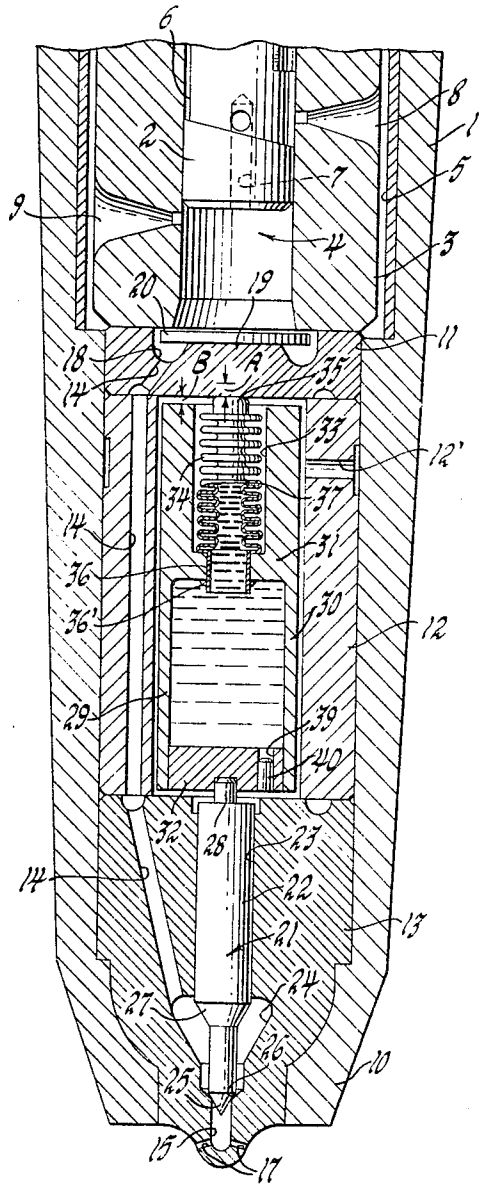


Fig. 1

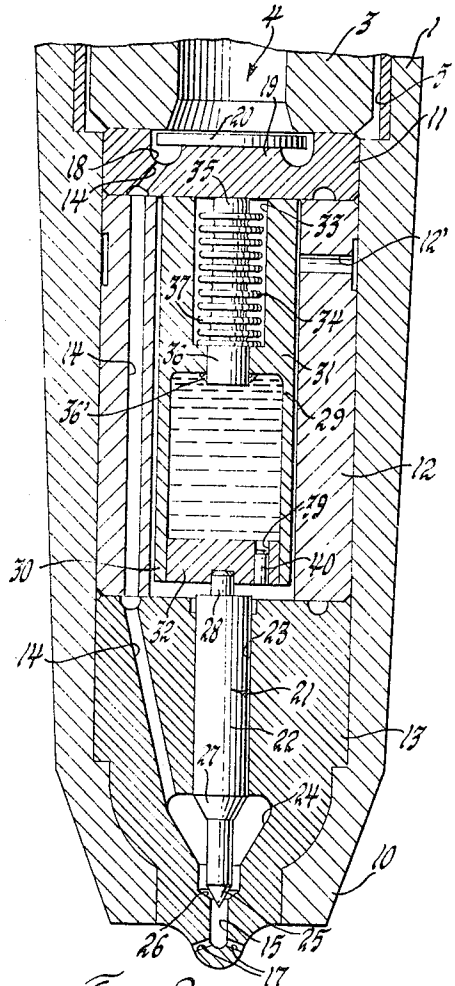


Fig. 2

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UNIT FUEL INJECTOR WITH FLUID INJECTION VALVE SPRING

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6 Claims. (Cl. 239—533)

This invention relates to fuel injection apparatus and particularly to the injection valve control springs thereof.

Injectors of the so-called solid fuel type for introducing liquid fuel into engine cylinders conventionally include a normally closed injection control valve which is biased to its closed position by a spring and is openable against the biasing force of the spring by fuel pressure acting on the valve in an opening direction. The spring means generally comprises one or more metail coil springs arranged coaxially with the valve and located in a spring chamber in the body of the injector. Certain disadvantages are experienced in the use of such coil springs, including possibility of breakage in operation, variation in load-deflection rate occasioned by slight differences in manufacture or dimensions of the spring as installed, and limitations which the use of such springs impose on minimizing the size of the injector.

It is the principal object of our invention to substitute, for such conventional coil springs, a liquid or fluid spring which is positively sealed against leakage. By confining a relatively small quantity (in the order of a fraction of a cubic inch) of a suitable fluid in a closed chamber with an opening through which the thrust of the valve can be applied to compress the fluid in the chamber, the elasticity of the fluid will function to resiliently control opening travel of the valve without the aforementioned and other disadvantages of such injectors employing coil springs. To avoid any leakage problem with the confined fluid, we employ a chamber comprising a hollow rigid member and a flexible wall member which is in fluid communication with the interior of the rigid member through an opening in the latter. Then by connecting one of these members to move with the injector valve, while supporting the other against such movement, the compressibility of the fluid in resiliently opposing valve opening movement is utilized without possibility of leakage of the compressed fluid. Silicone has been found to serve as a suitable fluid for such a "spring" on account of its relatively constant and fairly high viscosity, and its relatively low bulk modulus of elasticity, resistance to heat, noncorrosive qualities, etc.

Further, by proper dimensioning of the parts the fluid making up the spring body can be arranged to exert a preload on the valve sufficient to hold it in closed position until a desired fuel pressure is built up in the injector to effect opening of the valve, thereby insuring positive valve closing action after each injection.

These and other objects and advantages of the invention will be better understood from the following description of one illustrative embodiment thereof, having reference to the drawing, wherein:

FIGURE 1 is a longitudinal sectional view through the injector and lower pump portion of a unit injector-pump having a fluid spring controlling the injection valve in accordance with the invention, the parts being shown in their "valve closed" positions.

FIGURE 2 is a view similar to FIGURE 1 but showing the parts in their "valve open" positions.

The unit fuel injector shown has the usual outer housing **1** enclosing a plunger type fuel pump in its upper end and a fuel injector in the lower end. The plunger **2** of the pump is reciprocable in a bushing **3** to develop a fuel charge in the pumping chamber **4** within the lower

end of the bushing. The means for effecting reciprocation of the plunger and for introducing fuel into the receiving chamber **5** surrounding the bushing are not shown since they form no part of the present invention and may be of conventional construction such as shown, for example, in U.S. Patent 3,006,556 to Shade et al. It suffices to add here that the plunger has an external groove **6** which is connected by an internal passage **7** with the pump chamber **4**, and the bushing has upper and lower ports **8** and **9** which cooperate with the groove **6** and passage **7** during each downward stroke of the plunger to deliver a charge of fuel under injection pressure through the lower end of the bushing **3**.

In stacked endwise abutment between the lower end of the bushing and the lower end **10** of the housing are a check valve cage **11**, a tubular spring chamber **12** and a spray tip **13**. Through each of these three parts extends a fuel delivery passage **14** which terminates at its lower end in a fuel outlet **15**, in the form of a short passage leading to a plurality of spray orifices **17** in the bottom of the spray tip **13**. It is through these spray orifices that the fuel enters the engine cylinder (not shown) during each injection. At its upper end, the fuel delivery passage is connected with the pump chamber **4** through an annular groove **18** in the upper end of the check valve cage **11**. Centrally of this groove is an abutment **19** on which normally rests a flat check valve **20** which is engageable with the lower end of the bushing **3** to block reverse flow through the passage **14** into the pump chamber from the engine in the event the injection valve **21** should fail to close. A vent passage **12'** is provided in the side wall of the spring chamber **12** for escape (via clearance between the spring chamber and check cage **11** internally of the housing **1**) to the fuel receiving chamber **5** of any leakage fuel entering the spring chamber past the needle valve **21**.

The injection valve **21** is illustrated as being of the needle type having a main body portion **22** slidably reciprocable in a bore **23** in the spray tip **13**. The lower end of this bore terminates in an enlargement or cavity **24** common with the fuel delivery passage **14** immediately above the fuel outlet **15**. The lower end of the needle valve is shown terminating with a conical point **25** which is engageable with a seat **26** to close the outlet **15** when the valve is in its lowermost or "closed" position shown in FIGURE 1. A conical shoulder **27** between the main body portion **22** of the valve and its seat-engageable point **25** is exposed to fuel pressure tending to move the valve upwardly in the spray tip to its "open" position shown in FIGURE 2.

At its upper end, the valve has an extension **28** of reduced diameter which projects above the upper end of the spray tip **13**. Loosely slidable within the tubular spring chamber **12** is a rigid member in the form of a hollow steel body **29** having side walls **30** and upper and lower end walls **31** and **32**. For manufacturing purposes, the lower end wall **32** may be made separately and pressed into and brazed or otherwise secured in leak-tight relation with the lower end of the side walls **30**. The bottom face of this lower end wall **32** is recessed to socketably receive and bottom on the valve extension **28**. The upper end wall **31** is of considerable thickness, as shown, and is provided with a recess **33** in its upper face for enclosing a bellows **34**. This bellows which may be made of stainless steel or other suitable resilient, but relatively stiff material, is closed at its upper end by a fixed head **35** which normally projects out of the recess **33** and is at all times in abutment with the check valve cage **11**. The lower end of the bellows terminates in a head or nipple portion **36** which extends through the bottom wall of the recess **33** and forms an opening which connects the interior of the bellows with the interior of

the hollow rigid body **29**. A tight, leakproof joint is obtained as by brazing at **36'** between the bellows lower head **36** and the end wall **31**. The side walls of the bellows are convoluted in conventional manner, as indicated by the numeral **37**, and the mean of the inner and outer diameters of these convolutions may be taken as the effective diameter of the bellows.

Completely filling the interior of the rigid body **29** and the bellows **34** is a quantity of silicone fluid of sufficient volume to exert pressure via the end wall **32** to maintain the valve **21** normally closed. The silicone fluid may be initially introduced through an opening **39** in the body end wall **32**, after which this opening is sealed with a plug **40**. The length of the rigid body **29** is such that with the valve in closed position the upper end wall **31** terminates a distance B below the check valve cage **11**. Prior to installing the body **29** with its assembled bellows in place between the injection valve **21** and the check valve cage **11**, the upper head **35** of the bellows projects a further distance A outwardly of the recess **33**.

This distance A is taken up during assembly of the injector by endwise clamping of the body **29** and bellows **34** between check valve cage **11** and the needle valve in closed position as shown in FIGURE 1. As a result, the silicone fluid is under a certain initial pressure and the convoluted side walls of the bellows are also under some compressive load, producing a combined force tending to hold the injection valve seated. By properly selecting the extent of this preloading distance A, in relation to the area of the conical valve face **27** and the load-deflection rate of the bellows, a predetermined initial fuel pressure required to open the valve may be established. Thus, during operation of the injector, as fuel pressure is developed in the pump chamber **4** and passage **14** in excess of this initial fuel pressure, the valve is forced open against the combined biasing force of the silicone fluid and resilience of the bellows to enable fuel injection to begin.

Although the required dimensions of the various parts will, of course, vary to meet the requirements of different size fuel injectors, desired valve opening pressures, stroke, etc., the following specifications may be used as guide lines in applying the principles of our invention to such an injector of more or less conventional type. Using silicone as the fluid and a commercially available, stainless steel bellows having a load-deflection rate of 280 pounds per inch and an effective area of .033 square inch, it will be assumed that a needle valve opening fuel pressure of 2,000 p.s.i. is desired. For a needle valve area **27** of .028 square inch, the initial pressure of this fluid required to restrain opening of the valve under the 2,000 p.s.i. fuel pressure may be calculated in terms of the preloading distance A, as follows:

$$\text{Fluid initial pressure}=\frac{2{,}000\times.028-280\times A}{.033}$$

and using a preloading distance A of, say .045 inch, this fluid initial pressure becomes:

$$\frac{2{,}000\times.028-280\times.045}{.033}=1315 \text{ p.s.i.}$$

Also, since the bulk modulus of elasticity of the silicone fluid may be taken as 150,000 p.s.i., the free volume required thereof to obtain this 1315 p.s.i. initial fluid pressure with the .033 square inch effective area bellows preloaded the distance A of .045 inch may be calculated as follows:

$$\text{Free fluid volume}=\frac{150{,}000\times.033\times.045}{1315}=.1695 \text{ cu. in.}$$

It will also be seen that opening movement of the valve is a function of the product of the valve area **27** times the fuel pressure in the passage **14**, divided by the sum

of the bellows load-deflection rate and the product of the bellows effective area times the ratio of the fluid bulk modulus of elasticity to the fluid free volume; since:

Fuel pressure force=bellows reaction force+fluid pressure force

and, in terms of maximum valve opening movement B:

$$\text{Bellows reaction force}=280(.045+B)$$

$$\text{Fluid pressure force}=\frac{.033\times150{,}000\times(.045+B)}{.1695}$$

$$\text{Fuel pressure}\times.028=280(.045+B)+\frac{.033\times150{,}000(.045+B)}{.1695}$$

therefore:

$$B=\frac{\text{fuel pressure}\times.028}{280+\frac{.033\times150{,}000}{.1695}}-.045$$

At valve "full open" position (B=.016 inch) the required fuel pressure in passage **14** would be:

$$\text{Fuel pressure}=\frac{280(.045+.016)+\frac{(.033)^2\times150{,}000(.045+.016)}{.1695}}{.028}$$

$$=\frac{58.75+17.07}{.028}=2707 \text{ p.s.i.}$$

It will be understood that while only one embodiment of the invention has been shown and described specifically for purposes of illustration, various changes in the parts and their arrangement may be made without departing from the spirit and scope of the following claims.

We claim:

1. In a fuel injector, a valve body having a passage for the reception of fuel under injection pressure, said passage terminating in an outlet, a valve movable to open and close said outlet and having an area against which said fuel pressure acts to move the valve in the opening direction, and a spring opposing opening movement of the valve, said spring comprising a quantity of fluid, means confining said fluid under pressure including a bellows having a fixed head and a head connected to the valve for movement toward said fixed head with opening movement of the valve, the compressibility of said fluid within said means under the thrust force of said fuel pressure on said valve area accommodating opening of the valve.

2. In a fuel injector having a valve body with a passage for the reception of fuel under injection pressure, said passage terminating in an outlet, a valve operative to close said outlet and having an area against which pressure of the fuel in said passage acts in the valve opening direction, and a spring biasing said valve closed but yieldable to accommodate opening of the valve in response to the force of said fuel injection pressure on said area, the improvement wherein said spring consists of a quantity of fluid and a chamber confining said fluid under pressure, said chamber including a hollow member having rigid walls, a flexible wall member and an opening through which the pressure of said fluid within said hollow member is subjected to said flexible wall member, and means connecting one of said members to the valve for movement therewith while supporting the other of said members against said movement.

3. In a unit fuel injector having a pump chamber with a plunger therein for developing an injection charge of fuel under pressure, a fuel charge delivery passage leading from said pump chamber and terminating with an outlet, a valve normally closing said outlet but having an area exposed to fuel pressure in said passage and operable to open said valve in response to said pressure reaching a predetermined value, and a spring yieldably opposing

opening movement of said valve, said spring comprising a quantity of fluid and a chamber confining said fluid, said chamber including a rigid hollow body having an opening and a bellows, said bellows having a fixed head and a movable head, said movable head being connected to the valve for movement toward said fixed head with opening movement of the valve, said movable head having an opening through which the interior of the bellows is in direct fluid pressure communication with the interior of said body via said body opening, said bellows having an effective area against which said fluid pressure acts in opposing said movement of said movable head, said chamber being of sufficient volume in relation to said effective area and the modulus of elasticity of said fluid to accommodate said movement upon application of injection pressure to the fuel in said passage.

4. The invention of claim 3, wherein said bellows has convoluted side walls of resiliently flexible material interconnecting said fixed and movable heads and defining said effective area, whereby resistance to flexure of said side walls opposes opening movement of the valve with a force supplementing the force of said fluid pressure against said effective area.

5. The invention of claim 4, wherein said fluid is under an initial pressure within said chamber when said valve is in closed position.

6. The invention of claim 3, wherein said rigid hollow body has an end wall in abutment with said valve and an opposite end wall with a recess facing said pump chamber, said bellows being located in said recess and having its movable head and opening connected to said body in the bottom of said recess and having its fixed head projecting out of said recess when said valve is in closed position, and a fixed member supporting said fixed head against movement with said body during valve opening movement and limiting said body movement and thereby said valve opening movement.

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EVERETT W. KIRBY, *Primary Examiner.*