United States Patent

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[54] **FUEL INJECTOR**
17 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **239/95,** 239/383, 239/453, 239/533; 123/188
[51] **Int. Cl.** **F02m 45/10**
[50] **Field of Search** 239/86, 95, 453, 383, 533; 123/90, 188

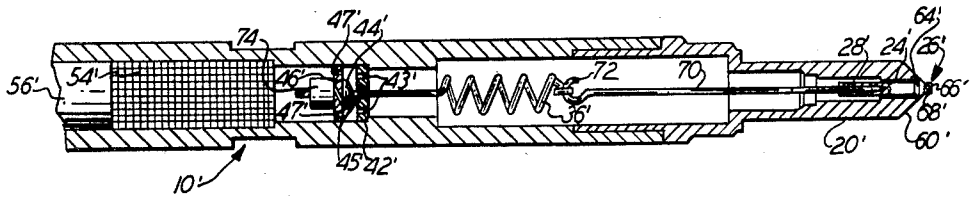
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ABSTRACT: An axially movable, outwardly opening valve member seats on an outwardly tapered seat portion in the tip of the fuel injector about 0.005 inch upstream of the seat outer edge. A tension spring located within the fuel passage urges the valve member to its seat and also holds the valve member on the center line of the injector. The spring is designed to resonate the valve member at 250—1,200 cycles per second in stationary air. A rotator fastened to the upstream end of the tension spring utilizes the dynamics of the fuel injection to rotate the valve member.



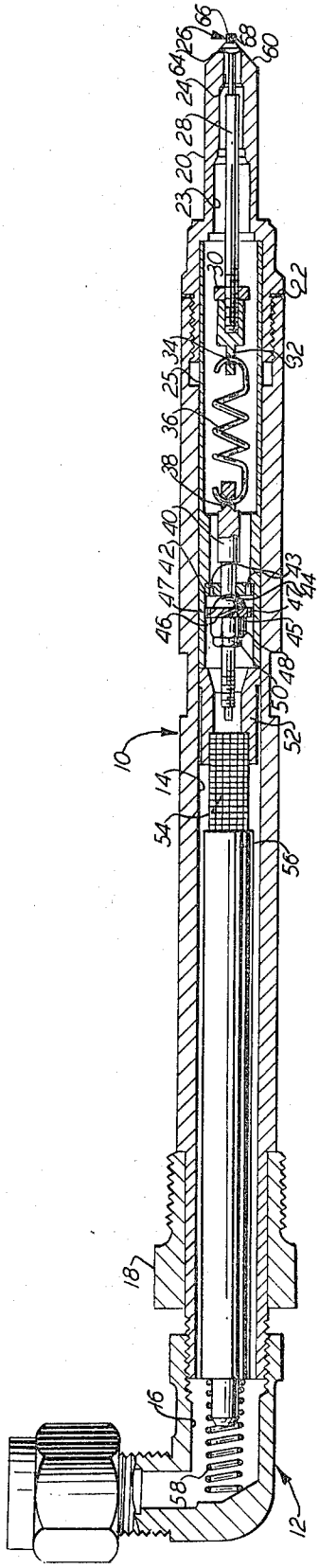


FIG. 1

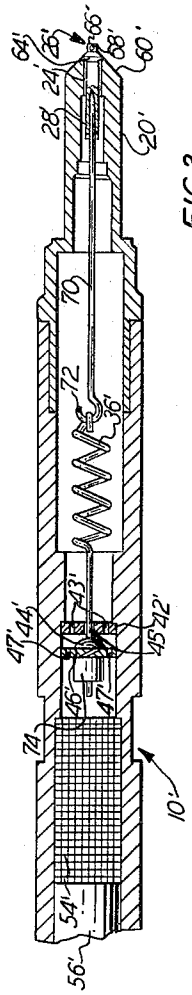


FIG. 3

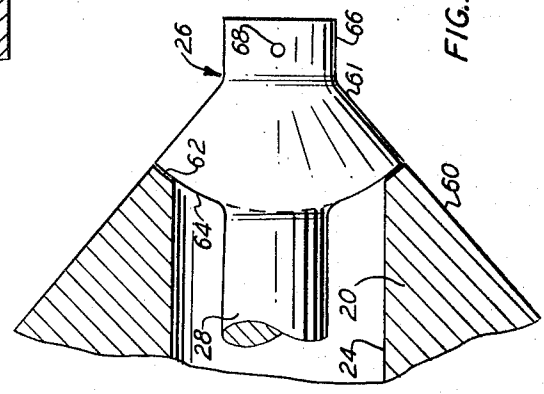


FIG. 2

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FUEL INJECTOR

SUMMARY OF THE INVENTION

Fuel injectors for reciprocating internal combustion engines must satisfy a variety of requirements throughout a wide flow range for proper engine operation from idling to over 7,000 r.p.m. Such injectors must start and stop fuel flow uniformly without dripping at the end of the injection cycle, produce a spray having a substantially uniform concentricity throughout each injection cycle at the various fuel flow rates, and perform with a minimum of combustion deposit buildup. Other practical considerations conductive to commercial acceptance include minimizing wear, insuring that the wear which does occur is uniform, and reducing material and manufacturing costs.

The injector of this invention is particularly useful in a stratified charge type internal combustion engine such as the engine described in Bishop et al., U.S. Pat. No. 3,315,650. Accurate fuel delivery over a wide range of flow rates is essential in such an engine, and this injector performs exceptionally well in achieving the optimum performance and economy of the engine. Many features of the injector also are useful in conventional fuel injected reciprocating-type engines.

An elongated body having an inwardly tapering tip portion, a passage extending through the body and tip portion, and an outwardly tapering seat at the opening of the passage form the basic structure of the injector of this invention. An axially movable poppet-type valve member normally seats on the seat portion but is moved away therefrom by fuel pressure. The seat and the valve member are designed so the valve member initially contacts the seat about 0.002—0.010 inch from the downstream edge of the seat portion. One end of a tension spring located in the body passage is connected to the valve member and the other end is anchored in the body so the spring holds the valve member on the center line of the tip and the body and draws the valve member toward its seat.

Valve member rotation improves seat life and reduces the buildup of combustion deposits on the injector tip. This rotation is provided by a hydrodynamic rotator connected to the upstream end of the spring. Rotational torque is developed on the slanted passages in the rotator by pressure pulses propagating upstream from the vibrating valve member. The spring can be connected to the valve member through an eye arrangement permitting some rotational movement of the spring relative to the valve body. When the valve member is lifted off its seat by fuel delivery, friction on the valve member drops essentially to zero and valve rotation takes place.

Vibrating the valve member during fuel delivery assures good fuel atomization with fuel pressures of 150—800 p.s.i. Valve vibration in the entire load and speed range, including engine startup, is achieved by an essentially zero friction valve guidance arrangement and proper tuning of the spring and valve member assembly with the fuel system communicating with the injector. A spring having a spring rate capable of producing a resonant frequency of the spring and valve assembly in stationary air of about 250—1,200 cycles per second produces good valve vibration in the entire operating range. The fuel flow area of the injector and the fuel line also are important in achieving good vibration.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side sectional view of an injector of this invention for a gasoline engine showing the general arrangement of the components.

FIG. 2 is an enlarged view of the injector tip portion showing the valve member seating arrangement, the angular relationship of the valve seat and the valve exterior, and the planar relationship of the tip exterior and the valve member exterior in the vicinity of the seat.

FIG. 3 is a sectional view showing a less expensive injector having a simplified rotator and a more easily manufactured construction.

DETAILED DESCRIPTION

Referring to FIG. 1, a cylindrical valve body **10** has one end exteriorly threaded into an inlet fitting **12**. A substantially concentric passage **14** extends through body **10** and communicates with the passage **16** in fitting **12**. The upstream exterior portion of body **10** has a holder nut **18** slidably mounted thereon to fasten the injector into the engine by conventional means.

A tip portion **20** is threadably fastened to the other end of body **10** and the threaded joint is sealed by a gasket **22**. Tip portion **20** necks down to an outside diameter approximately equaling the diameter of passage **14** and contains a passage **23** stepping down in a plurality of stages to its final passage **24**. Passage **14** communicates with passage **23**. A tubular sleeve **25** is fitted in passage **14** and extends into the larger end of the tip portion.

Located in the opening of passage **24** is a valve member **26** that has an elongated stem **28** extending upstream through passage **23** and into passage **14**. Stem **28** is considerably smaller than passage **23** so it does not restrict fuel flow. The upper end of stem **28** is threaded into an extension **30** that has a small tab **32** on its upstream end. A double chamfered hole **34** is formed in tab **32**.

A tension spring **36** having hooked eyes at each end has one eye inserted through hole **34** and the other eye inserted through a similar hole **38** in an anchor rod **40**. The double chamfers used on holes **34** and **38** provide knife edges that avoid transmitting any side loads to the valve member. Anchor rod **40** projects through an anchor seat **42** firmly pressed onto a shoulder in sleeve **25** at least 10 valve member diameters upstream from the valve member. A valve member diameter, as the term is used herein, is the diameter of the initial contact line between the valve member and its seat. Maintaining the anchor seat beyond this parameter permits the valve member to seek a concentric location during injection and seating.

Seat **42** has an appropriate number of holes **43** sufficient to pass fuel through the injector. A hemispherical bearing member **44** is positioned on rod **40** above seat **42** with its hemispherical surface contacting a conical portion **45** formed on the upstream side of seat **42**, and a valve rotator **46** is mounted on rod **40** just upstream of member **44**. Rotator **46** has a plurality of passages **47** located near its outer periphery and angled 45° relative to the body centerline. An anchor nut **48** and a jam nut **50** are threaded onto rod **40** to hold the rotator and bearing member in place. Bearing member **44**, rotator **46** and anchor nut **48** can be of one-piece construction if desired.

Sleeve **25** terminates a short distance upstream of the upper end of anchor rod **40** and a hollow filter carrier **52** seats on the upper end of the sleeve. A filter **54** seats in a counterbore in the upstream end of carrier **52** and is held in place by an elongated spacer **56** spring loaded in the downstream direction by a compressive spring **58** seating in inlet fitting **12**.

Turning to the enlarged view of the injector tip shown in FIG. 2, the exterior surface **60** of tip portion **20** tapers inwardly and intersects an outwardly tapering valve seat **62** at a substantially right angle. Stem **28** flows smoothly into a spherical surface **64** that serves as the seating surface of valve member **26**. Spherical surface **64** terminates at a point corresponding to the downstream edge of seat **62**, and the exterior surface **61** of valve member **26** then tapers inwardly at the angle of surface **60** until reaching the approximate diameter of stem **28**. Exterior surface **61** then flows smoothly into a short cylindrical portion **66** that has a diameter approximately equaling the diameter of stem **28**. A small hole **68** can be formed in cylindrical portion **66** to assist in assembly if desired.

Surface **61** of the valve member and surface **60** of the tip portion in the vicinity of the downstream edge of the seat are parallel to each other and preferably are coplanar within very close tolerances, usually about 0.0003 inch. This arrangement

provides worthwhile benefits in reducing deposits on the tip. It is preferable to have the valve member about 0.0002 inch larger than the tip portion initially, since valve seat wear then tends to match up the exterior surfaces.

Valve seat **62** is outwardly conical and spherical surface **64** is designed to contact seat **62** initially at a contact line about 0.005 inch from the downstream edge of seat **62**. As the valve or seat wear, this contact line of course becomes a contact surface. Each of the swivel joints provided by the end connections of spring **36** assist in eliminating any forces that cannot be resolved along the center line of valve member **26**. Such forces would tend to cock the valve member and thereby produce an asymmetrical spray pattern, cause uneven seat wear, and destroy the parallelism of surfaces **60** and **61**.

The size of valve member **26** is selected so there is a minimum of 0.0003 inch means valve lift at the minimum or idling flow rate and a maximum of 0.005 inch means valve lift at the maximum flow rate. Skip cycling at and near the idling flow rate is avoided by maintaining the valve size above this minimum; the maximum valve lift insures that the fuel sheet issuing from the injector does not become too thick to be atomized when the pressure drop through the injector is below 800 p.s.i., and assists in keeping the valve member concentric so the fuel sheet is approximately equal on all sides.

Stem **28** is considerably smaller than corresponding portions of passages **14**, **23** and **24**, and guidance of valve member **26** is provided entirely by the anchor rod assembly acting through the spring. Thus the valve member itself is not subjected to any mechanical guidance, and it can sway or rotate freely to seek a concentric position. Seat **42** preferably locates spherical bearing member **44** within 0° 5′ from a point on the centerline of the valve member.

Axial vibration of valve member **28** during injection assures proper fuel atomization with a pressure drop across the injector of 150—800 p.s.i. Adequate valve vibration is achieved with the zero friction guidance arrangement of the valve member by selecting a spring **36** having a rate sufficient to vibrate the valve member in stationary air at a frequency between 250 and 1,200 cycles per second. During fuel delivery the vibrating frequency can be outside of this range because of the effect of the fuel. For proper vibration and delivery, the fuel flow area of the injector for a distance 4—6 inches upstream of the valve member should be 1—3 times the valve diameter squared. In addition, the flow area of the fuel line should be such that the product of the maximum fuel flow rate of the pump in cubic inches per second and the line flow area in square inches is between 0.01 and 0.03.

The reverse pressure pulse passing upstream through passage **14** when the valve member stops fuel delivery acts on passages **47** in the valve rotator **46** to exert a rotating torque on the anchor rod assembly while simultaneously reducing the load between bearing member **44** and seat **42**. The reduced friction between bearing member **44** and seat **42** permits a slight windup of anchor rod assembly **40** that is temporarily absorbed by the ends of spring **36**. When the next vibration or injection cycle opens valve member **26**, the essentially zero friction of valve member **26** permits the slight torque to rotate the valve member. Because of the valve member vibration, satisfactory rotation also can be achieved with a rigid connection between the rotator and the valve member.

In the less expensive injector shown in FIG. **3**, components identical to those of FIG. **1** are designated by the same numerals and only changed and new components are described below. Tip portion **20′** is press fitted into body **10′**. Valve member **26′** has a shortened stem **28′** that is soldered to a wire **70**. Wire **70** has a hook **72** at its upstream end that engages the lower eye of a spring **36′**. Anchor seat **42′** is pressed onto a shoulder in body **10′** and the upper end of spring **36′** extends through anchor seat **42** and an assembly consisting of bearing member **44′**, rotator **46′**, and a fastener **74**. This assembly is fastened to spring **36′** by an adhesive such as "Locktite", which also can be used to fasten tip portion **20′** to body **10′**. Filter **54′** is pressed onto a shoulder in body **10′** upstream of the rotator assembly.

In place of spherical surface **64**, valve member **26** can have a double cone surface in which the inner cone terminates at the desired seat point and the outer cone projects downstream at a slightly sharper angle. The sphere-on-cone construction shown in FIG. **2** is preferred in most instances over such a cone-on-cone construction, however, because a higher surface finish can be achieved by lapping spherical surface **64**.

Thus this invention provides a fuel injector capable of extremely accurate fuel delivery over a wide range of flow rates. Painstaking engineering accommodates all performance requirements and the injector produces a uniform cone of fuel at each flow rate for the life of the engine. The initial contact line of the valve member on its seat prevents asymmetrical spray and deposit buildup, the guidance and spring arrangement insures valve member vibration and fuel atomization, and the coplanar relationship of the exterior surfaces of the tip and the valve member in the vicinity of the seat also assists in preventing deposits.

We claim:

1. A fuel injector comprising:

an elongated body having an inwardly tapering tip portion, a passage extending through said body and tip portion and an outwardly tapering seat portion at the opening of said passage in said tip portion;

an axially movable valve member normally seated on said seat portion but movable away therefrom, said valve member initially contacting said seat portion about 0.002—0.010 inch from the downstream edge of the seat portion;

spring means located in said passage, said spring means having one end connected to said valve member to urge the valve member into contact with the seat portion; and

rotator means located in said passage for utilizing the dynamics of fuel injection to apply a rotating torque to the valve member said rotator means being connected to the opposite end of said spring means.

2. The injector of claim **1** in which the exterior surface of the tip portion and the exterior surface of the valve member in the vicinity of the downstream edge of the seat portion are coplanar within 0.0003 inch to reduce combustion deposits.

3. The injector of claim **2** in which the valve member has a mean lift of about 0.0003 inch at engine idling and about 0.005 inch at maximum fuel flow.

4. The injector of claim **3** in which the spring means is capable of vibrating the valve member at a rate of 250—1,200 cycles per second in stationary air.

5. The injector of claim **4** in which the seat portion forms essentially a right angle with the exterior surface of the tip portion.

6. The injector of claim **5** comprising an anchor seat fastened to said body upstream of said valve member and a bearing member seating on the upstream side of said anchor seat, and said spring means is a tension spring having one end connected to said bearing member and the other end connected to the valve member.

7. The injector of claim **6** in which the rotator means is fastened to said anchor member, said rotator means comprising passages angled relative to the axis of the injector, said spring means providing a slight angular looseness between said bearing member and said valve member, said rotator means reacting to a reverse pressure wave to wind the rotator means slightly relative to the valve member when fuel delivery stops, said winding rotating the valve member when fuel delivery resumes.

8. The injector of claim **7** in which the spring means is fastened to the valve member by a double-chamfered hole that permits the slight angular looseness.

9. The injector of claim **8** in which the seat portion of the tip portion is outwardly conical and the seating surface of the valve member is spherical.

10. The injector of claim **1** in which the spring means is capable of vibrating the valve member at a rate of 250—1,200 cycles per second in stationary air.

11. The injector of claim 1 comprising an anchor seat fastened to said body upstream of said valve member and a bearing member seating on the upstream side of said anchor seat, and said spring means is a tension spring having one end connected to said bearing member and the other end connected to the valve member.

12. A fuel injector for a reciprocating internal combustion engine comprising:

an elongated body having an inwardly tapering tip portion, a passage extending through said body and tip portion and an outwardly tapering seat portion at the opening of said passage in said tip portion;

an axially movable valve member normally seated on said seat portion but movable away therefrom by fuel pressure in said passage;

an anchor seat located in said passage and fastened to said body upstream of said valve member;

a bearing member normally seated on the upstreamside of said anchor seat, said bearing member being rotatable relative to said anchor seat;

a tension spring connecting said bearing member and said valve member, said tension spring being capable of vibrating said valve member at a rate of 250—1,200 cycles per second in stationary air; and

rotator means fastened to said bearing member for utilizing the dynamics of fuel injection to exert a rotational torque on said bearing member, said spring means transmitting said rotational torque to said valve member.

13. The injector of claim 12 in which the anchor seat is at least 10 valve member diameters upstream from said valve member.

14. The injector of claim 13 in which the seating surface of the valve member is spherical, said seating surface initially contacting said seat portion about 0.002—0.010 inch from the downstream edge of the seat portion.

15. The injector of claim 14 comprising a filter means located within said body upstream of said anchor seat.

16. The injector of claim 15 in which the spring is bonded to the bearing member and has an eye engaging a tab fastened to the valve member.

17. The injector of claim 16 in which the valve member has a mean lift of about 0.0003 inch at engine idling and about 0.005 inch at maximum fuel flow.