United States Patent [19]

Butterfield et al.

[11] **3,836,080**

[45] **Sept. 17, 1974**

[54] **FUEL INJECTION NOZZLE**

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[22] Filed: **Sept. 10, 1973**

[21] Appl. No.: **395,828**

[52] **U.S. Cl.** **239/96,** 239/533
[51] **Int. Cl.** **F02m 41/16,** B05b 1/30
[58] **Field of Search** 239/96, 101, 533, 553, 239/562, 570, 584, 585, 590

[56] **References Cited**

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[57] **ABSTRACT**

In a fuel injection nozzle of the inwardly opening type wherein the spring-loaded nozzle valve is opened by metered pulses of high pressure fuel delivered in timed sequence by a fuel injection pump, an improved nozzle valve which reduces engine gaseous emissions and exhaust smoke by permitting a reduced sac volume. The minimum fuel flow through the valve is controlled by the valve element configuration rather than the valve seat intersection with the sac as in the conventional nozzle. The present nozzle construction facilitates manufacturing and permits a change of the valve delivery characteristics by modification of the valve element rather than the less accessible valve seat. The present construction provides an increased valve seat flow capacity for a given seat angle and valve lift.

10 Claims, 7 Drawing Figures

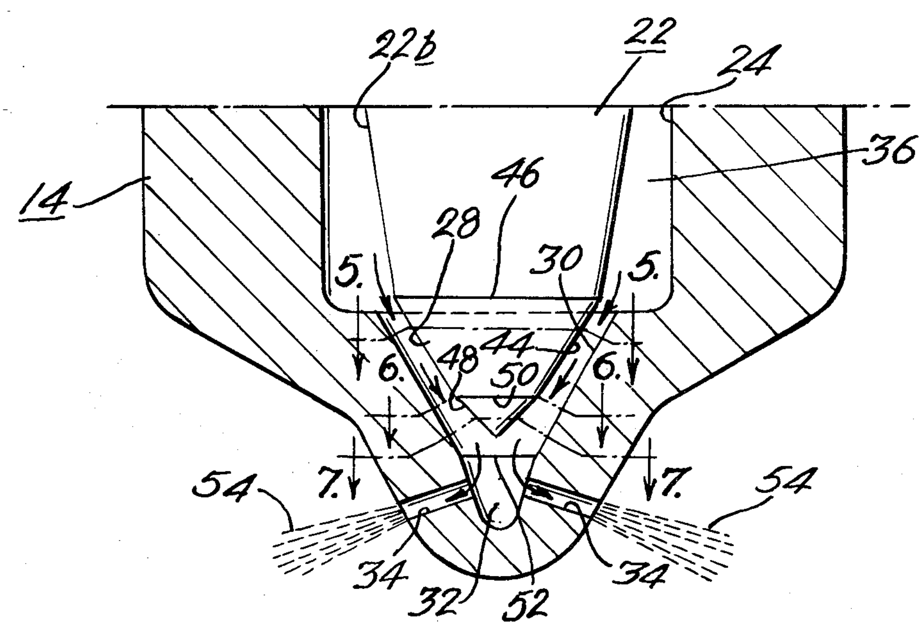

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FIG.1.

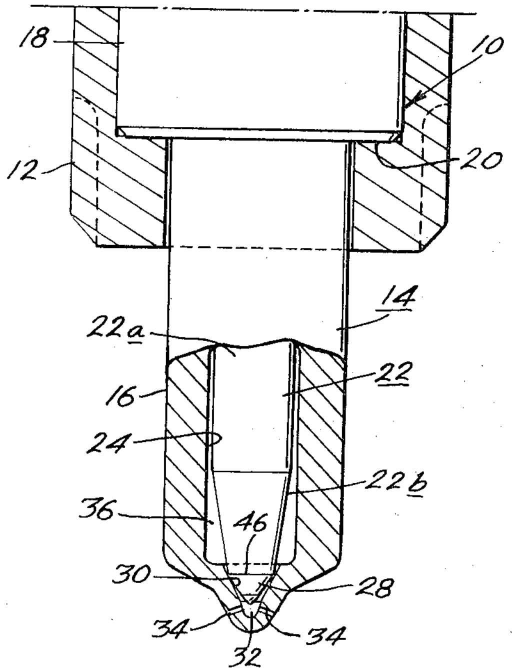


FIG.2.
(PRIOR ART)

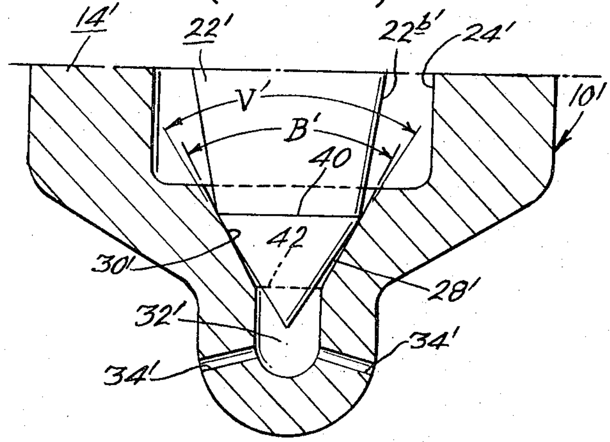


FIG.3.

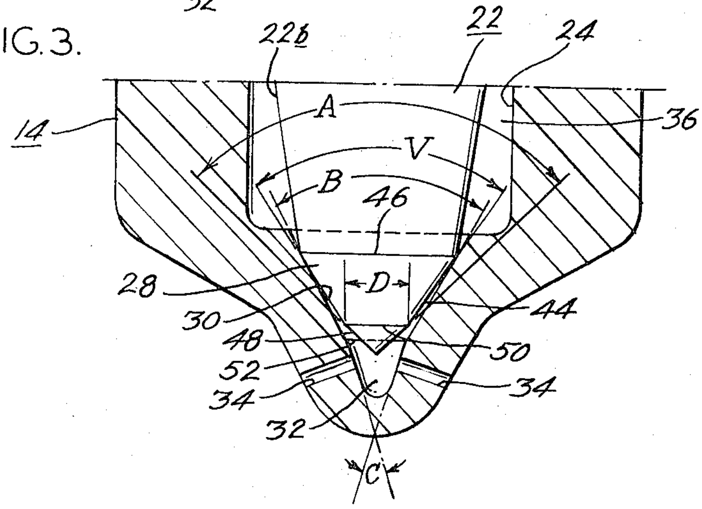


FIG.5.

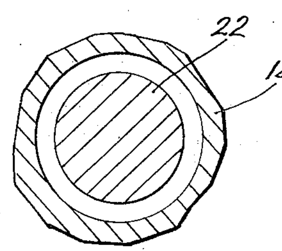


FIG.4.

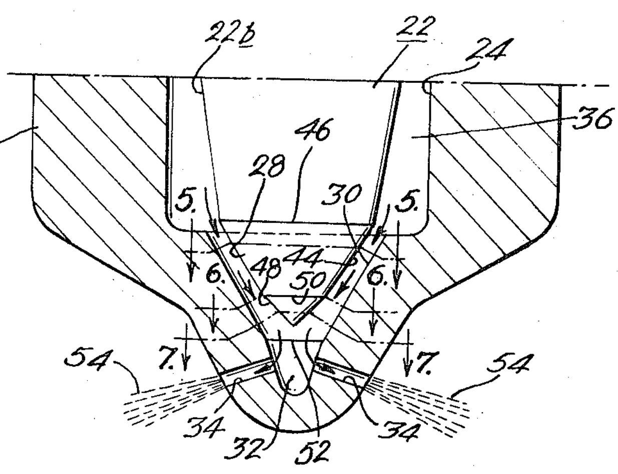


FIG.6.

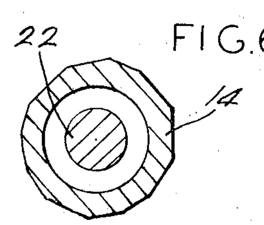
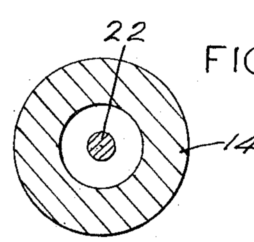


FIG.7.



FUEL INJECTION NOZZLE

The present invention relates generally to fuel injection nozzles for delivery of atomized fuel into the cylinders of internal combustion engines of the diesel type. More particularly, the invention relates to an improved fuel injection nozzle of the closed inwardly opening type having a nozzle valve design which minimizes engine gaseous emissions and exhaust smoke, facilitates manufacturing of the nozzle, and increases the valve seat flow capacity.

In the closed type of fuel injection nozzle, the nozzle tip extends into the engine combustion chamber so that the nozzle spray orifices are in a position to direct a spray of atomized fuel in a predetermined pattern within the combustion chamber. The spray orifices in a typical nozzle fan outwardly from a chamber known as the nozzle sac located immediately below the nozzle valve. A problem with the conventional nozzle is the boiling of the residual fuel in the sac chamber during combustion of the injected fuel in the engine chamber. Vaporized fuel from the sac escapes through the spray orifices into the combustion chamber but arrives too late for combustion with the injected charge and instead is exhausted from the engine with the products of combustion thereby increasing gaseous emissions and visual smoke. Although only a small amount of fuel escapes unburned in this manner, it is highly visible, particularly in the exhaust of automotive engines such as highway trucks. With the increasing emphasis on emission controls for automotive engines, the present invention is a timely and important advance in reducing the emission levels of diesel engines.

A further related problem is the chemical breakdown of the residual fuel in the sac chamber under the intense heat conditions of the combustion chamber, resulting in a fouling of the spray orifices and a buildup of carbon on the nozzle tip.

In the present invention the sac volume is substantially reduced in comparison to conventional nozzles, thereby reducing the amount of fuel remaining in the sac cavity following injection and minimizing the unburned fuel escaping to the exhaust from this source. It is the novel shape of the valve element which permits the reduction in sac volume. The valve element configuration is such as to establish the control point of minimum fuel flow with the valve element rather than at the intersection of the valve seat and sac as in the conventional nozzle. The sac may be smaller since it may now have converging walls. Allowance is unnecessary for finish grinding of the valve seat, and the valve element need not project into the sac when the valve is open. Since the seat flow characteristic of the nozzle may be controlled by machining the valve element rather than the relatively inaccessible sac and seat intersection, this operation is greatly facilitated. The improved shape of the valve element further increases the flexibility of manufacture of the nozzle since it permits an increase of the fuel flow area with a given valve lift simply by modifying the valve element with only a slight resultant increase in the volume of the sac cavity. Furthermore, since the improved valve shape provides increased flow at the seat for any given valve lift and any specific seat angle, it is therefore possible to reduce the valve lift in many applications to obtain the lowest possible nozzle seat and spring stresses for increased service life.

It is accordingly a first object of the present invention to provide an improved fuel injection nozzle which reduces engine gaseous emissions and visual smoke, and nozzle fouling by minimizing the volume of the nozzle sac cavity.

A further object of the invention is to provide an improved fuel injection nozzle as described having a novel valve element configuration which facilitates manufacturing of the nozzle.

Another object of the invention is to provide a fuel injection nozzle as described wherein the fuel flow characteristics of the nozzle may be varied by a change in the valve element configuration with only a slight resultant increase in the volume of the sac cavity.

Another object of the invention is to provide a fuel injection nozzle as described having a novel valve element configuration which provides either (1) increased fuel flow without changing valve seat angle or valve lift or (2) reduction in nozzle seat and spring stresses by reducing valve lift and maintaining existing fuel flow.

Additional objects and advantages of the invention will be readily apparent from the following detailed description of an embodiment thereof when taken together with the accompanying drawings wherein:

FIG. **1** is a partial side view partly in section of a nozzle assembly embodying the present invention;

FIG. **2** is an enlarged sectional view of the lower end of a conventional fuel injection nozzle;

FIG. **3** is an enlarged view of the lower end of the nozzle shown in FIG. **1**, showing the nozzle valve in the closed position;

FIG. **4** is a view similar to FIG. **3** with the valve shown in the open position;

FIG. **5** is a partial sectional view taken along line **5—5** of FIG. **4**;

FIG. **6** is a sectional view taken along line **6—6** of FIG. **4**; and

FIG. **7** is a sectional view taken along line **7—7** of FIG. **4**.

Referring to the drawings, FIG. **1** illustrates the lower portion of a fuel injection nozzle assembly generally designated **10** which for installation in an engine is secured to a nozzle holder (not shown) by the partially illustrated cap nut **12**. The nozzle assembly **10** includes a nozzle body **14** having a lower cylindrical portion **16** and an upper concentric cylindrical portion **18** of larger diameter. The cap nut **12** bears against the shoulder **20** formed at the juncture of the body portions **16** and **18**.

A valve element **22** is disposed within a concentric bore **24** in the nozzle body **14**. The valve element includes a cylindrical upper portion **22*a*** and a tapered lower portion **22*b***, and terminates at its lower end in a valve tip **28** having a novel configuration as described in detail below. The valve tip is adapted to cooperatively engage a frusto-conical valve seat **30** in the nozzle body which extends coaxially downwardly from the bore **24**. A smaller chamber **32** known in the art as a sac is disposed immediately beneath and in communication with the valve seat. A plurality of spray orifices **34** extend outwardly through the valve body substantially perpendicularly to the walls of the sac. The exterior of the nozzle body in the region of the sac is shaped in a nipple-like configuration to permit a substantially lateral direction of the fuel spray even in the case of asymmetrical spray orifices.

The valve element is downwardly spring-loaded into the closed position illustrated in FIG. **1.** Fuel from a fuel injection pump flows downwardly through annular passage **36** between the valve element and the bore wall and acts against the valve element to open the valve when the fuel pressure exceeds the spring force. The high pressure fuel flows into the sac, and is atomized as it passes out through the spray orifices into the combustion chamber. A drop in fuel pressure permits the valve to close under the spring force, cutting off the injection.

As indicated above, the present invention comprises essentially the cooperative configurations of the valve element tip, the valve seat and the sac, which details are most readily apparent from the views of FIGS. **3–7.** Prior to considering the details of the invention in these areas, however, it would be advantageous to review conventional nozzle tip construction as shown in FIG. **2** where elements common to the above described nozzle are designated by the same numerals with a prime subscript.

Referring to FIG. **2,** the prior art nozzle assembly **10'** includes a nozzle body **14'** and a valve element **22'** disposed within the bore **24'** of the body. The body **14'** includes a valve seat **30'** having a frusto-conical configuration, the diametrically opposed walls of which when viewed in section as in FIG. **2** form the included angle B'. The valve tip **28'** comprises a conical surface which intersects the tapered valve element portion **22***b*' to form the circular edge **40.** The diametrically opposed edges of the conical valve tip **28'** form therebetween the included angle V' which is a slightly larger angle than angle B' of the valve seat so that the valve element will engage the valve seat in its closed position along the circular edge **40.** The sac **32'** of the conventional nozzle is relatively large and of cylindrical shape with a semi-spherical end for reasons set forth below. The spray orifices **34'** extending outwardly from the sac **32'** direct atomized fuel in a predetermined spray pattern into the engine cylinder when the nozzle valve is opened.

In the prior art nozzle described, the minimum fuel flow area when the valve is in the open position occurs at the circular control edge **42** formed by the intersection of the valve seat and the cylindrical walls of the sac. Since the typical nozzle is many times smaller than the views shown (the spray orifices are barely visible to the unaided human eye), the machining of the valve seat and sac, which are relatively inaccessible at the bottom of the valve body is a difficult and time consuming operation. Since the valve seat **30'** in the conventional nozzle is finish ground after heat treatment, it can be understood that the sac walls must be cylindrical and concentric so that the control edge **42** will not change as the valve seat is ground. Furthermore, a sufficient volume of the sac must be provided to permit the extending valve tip conical surface **28'** to protrude into the sac cavity. This protruding portion cooperates with the edge **42** when the valve elements is in the open position to control the rate of fuel flow. The conventional nozzle accordingly must include a sac of an undesirably large volume.

Referring back to the present nozzle construction as shown in the enlarged views of FIGS. **3–7,** the valve tip **28** comprises a frusto-conical surface **44,** diametrically opposed faces of which are angled at the included angle V as shown in FIG. **3.** This frusto-conical surface **44** intersects the tapered valve element surface **22***b* at the circular edge **46.** The valve tip terminates in a conical surface **48,** diametrically opposed faces of which form the included angle A as shown in FIG. **3.** The conical surface **48** intersects the frusto-conical surface **44** to form the circular control edge **50** which has the diameter D as illustrated in FIG. **3.** The diametrically opposed walls of the valve seat **30** as shown in FIG. **3** form the included angle B which is slightly less than the included angle V of the valve element surface **44.** Accordingly, the valve element will contact the seat along the edge **46** in the closed position as shown in FIG. **3.** The sidewalls of the sac **32** have a frusto-conical configuration, diametrically opposed faces of which form the included angle C therebetween. The angle C being a smaller angle than the angle B of the valve seat, a circular edge **52** is formed at the intersection of the sac with the valve seat.

From the sectional views of FIGS. **5–7,** it can be seen that the area of minimum fuel flow in the open position of the valve is located between the control edge **50** (FIG. **6**) of the valve element and the valve seat. The angle A of the conical surface **48** is chosen so as to insure an increased flow area below the control edge **50** for any position of the valve element.

The operation of the present nozzle is best shown in FIG. **4** wherein the valve element is illustrated in the open position. As shown by the flow indicating arrows, the high pressure fuel passes from the annular passage **36** between the valve seat and the valve element surfaces **44** and **48** into the sac **32.** The rate of flow is determined by the minimum fuel flow area adjacent the control edge **50,** the diameter D of which governs the nozzle delivery characteristics. From the sac **32,** the fuel passes through the spray orifices **34** and exits as an atomized spray **54** into the engine combustion chamber.

With the control of nozzle seat minimum fuel flow at the valve element control edge **50,** the injection characteristics of the nozzle can be effected by machining the surface **48** while maintaining the angle A. This serves to enlarge the diameter D of the control edge **50,** thereby increasing the fuel flow area with only a slight resultant increase in the sac volume.

Since the minimum fuel control point is shifted from its conventional location at the intersection of the sac and seat walls, the sac can be shaped with frusto-conical walls to minimize its volume. The sac wall angle C should, however, be less than the seat angle B to provide run-out clearance for seat grinding. The sac depth can be considerably reduced since no cylindrical sac is required for seat flow control. Furthermore, the valve element tip with the present construction does not extend to an appreciable depth into the sac. For these several reasons, the present nozzle valve construction permits a substantial decrease in sac volume in comparison to conventional nozzles, with a consequent reduction in engine gaseous emission and visual smoke. It has been found in at least one instance that a nozzle utilizing the present design need have only 11 percent of the sac volume that would be necessary using the conventional construction. The reduction in sac volume coupled with the greatly facilitated manufacture and increased seat flow capacity of the nozzle possible with the present construction accordingly provides both an improved nozzle performance from an emission control standpoint and increased economies and flexibility of manufacture.

While a primary advantage of the present nozzle construction is the permissible reduction of the sac volume, it would of course be possible to utilize the valve construction with a conventional sac configuration and still achieve many of the described functional advantages such as increased flow capacity, ease of manufacture and extended service life.

Manifestly, changes in details of construction can be effected by those skilled in the art without departing from the spirit and scope of the present invention.

We claim:

1. In a fuel injection nozzle assembly comprising a nozzle body, a bore within said body, a valve element disposed within said bore for recipricatory movement between open and closed positions, a frusto-conical valve seat at the lower end of said bore, the lower end of said valve element being adapted to engage said valve seat to seal the passage therebetween, a sac beneath said valve seat in communication therewith, spray orifices extending outwardly through said valve body from said sac, and means for introducing pressurized fuel into said bore above said valve seat, the improvement comprising a circular control edge on said valve element lower end which defines in cooperation with said valve seat the minimum fuel flow area between said valve element and said valve seat in the open position of said valve element.

2. The invention claimed in claim **1** wherein said control edge is formed by the intersection of two surfaces of revolution on said valve element.

3. The invention claimed in claim **2** wherein one of said surfaces of revolution is a conical surface.

4. The invention claimed in claim **1** wherein the side walls of said sac have a frusto-conical configuration.

5. The invention claimed in claim **4** wherein the included angle of said frusto-conical valve seat is greater than that of said sac walls.

6. In a fuel injection nozzle assembly comprising a nozzle body, a bore within said body, a valve element disposed within said bore for recipricatory movement between open and closed positions, a frusto-conical valve seat at the lower end of said bore, the lower end of said valve element being adapted to engage said valve seat to seal the passage therebetween, a sac beneath said valve seat in communication therewith, spray orifices extending outwardly through said valve body from said sac, and means for introducing pressurized fuel into said bore above said valve seat, the improvement wherein said valve element lower end configuration comprises a conical surface at the valve element tip, and a frusto-conical surface adjacent said conical surface, the intersection of said conical and frusto-conical valve element surfaces forming a circular control edge which cooperates with said valve seat to define the minimum fuel flow area between said valve element and said valve seat in the open position of said valve element.

7. The invention claimed in claim **6** wherein the included angle of said valve element frusto-conical surface is greater than that of said valve seat.

8. The invention claimed in claim **6** wherein the included angle of said valve element conical surface is greater than that of said valve element frusto-conical surface so that the fuel flow area below said control edge is greater than that at said control edge at any position of said valve element.

9. The invention claimed in claim **6** wherein the side walls of said sac have a frusto-conical configuration.

10. The invention claimed in claim **9** wherein the included angle of said frusto-conical valve seat is greater than that of said sac walls.

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