June 11, 1968 F. DE LUCA 3,387,790

FUEL INJECTION NOZZLE

Filed April 11, 1967 3 Sheets-Sheet 1

FIG. 1.

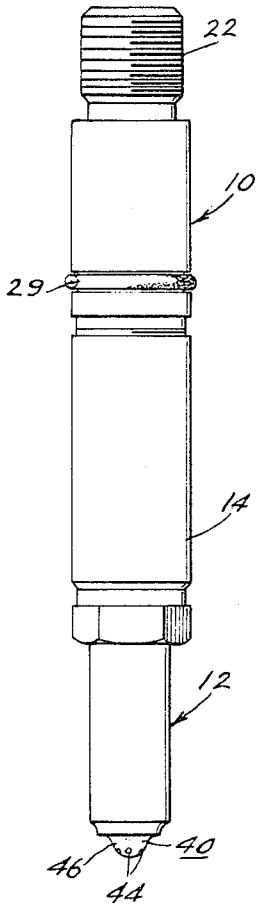
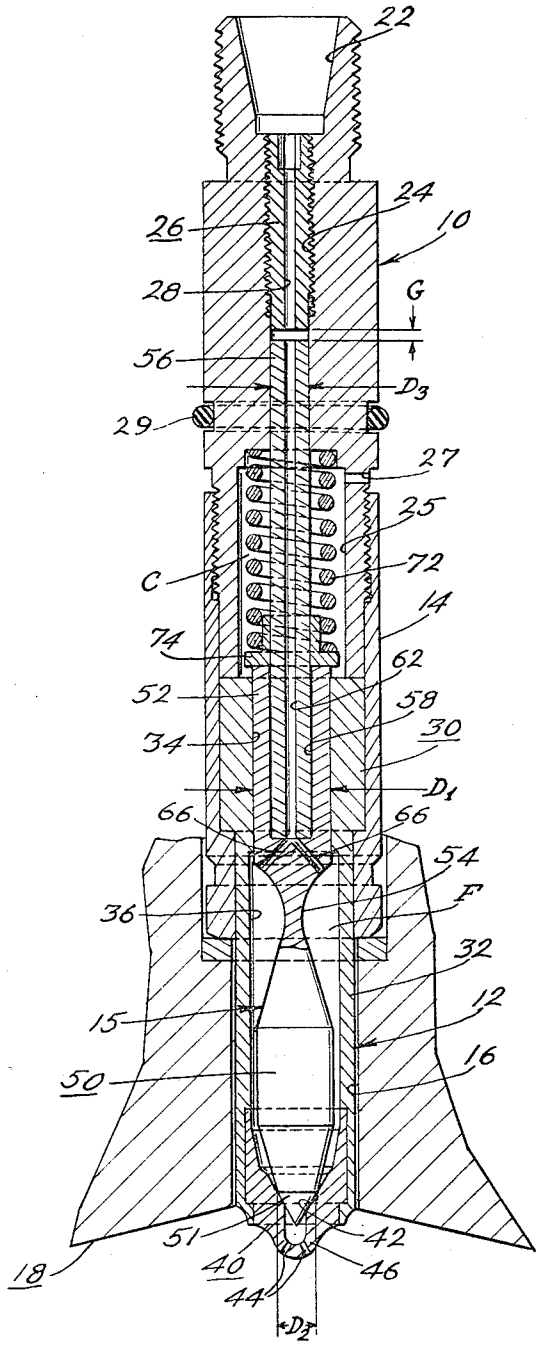


FIG. 2.



INVENTOR:
FRANK DE LUCA

BY Howson & Howson

ATTYS.

June 11, 1968 F. DE LUCA 3,387,790

FUEL INJECTION NOZZLE

Filed April 11, 1967 3 Sheets-Sheet 2

FIG.3.

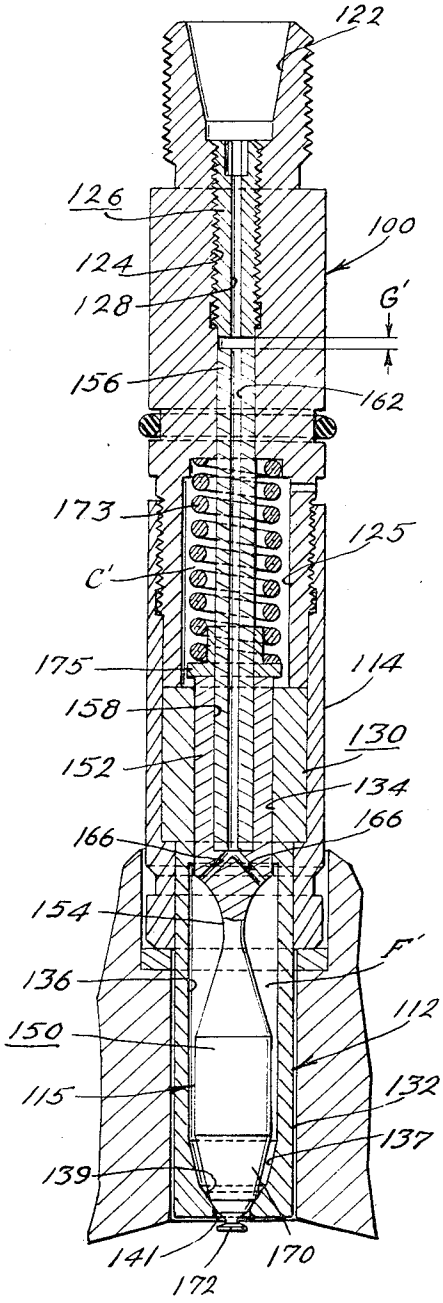


FIG.4.

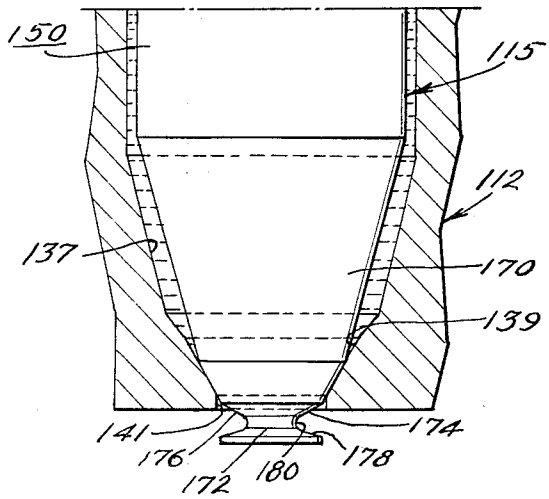
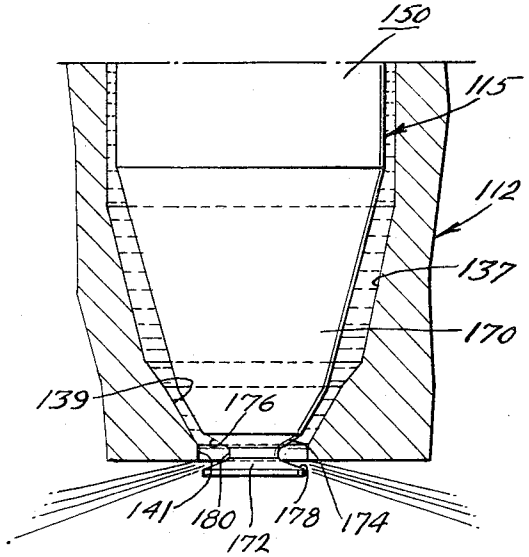


FIG.5.



INVENTOR:
FRANK DE LUCA

BY Howson & Howson

ATTYS.

June 11, 1968 F. DE LUCA 3,387,790

FUEL INJECTION NOZZLE

Filed April 11, 1967 3 Sheets-Sheet 3

FIG. 6.

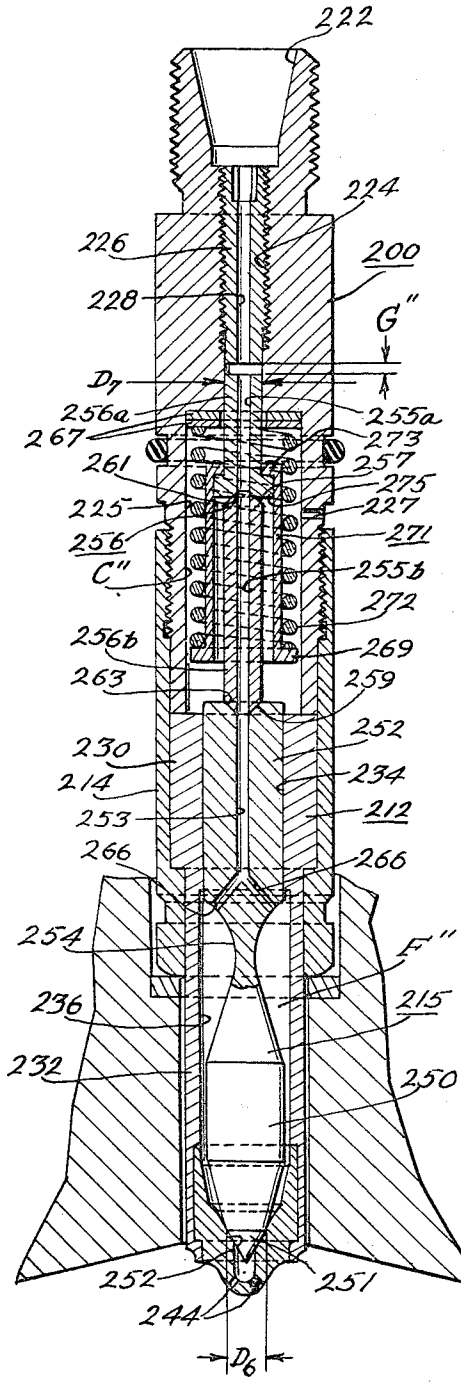
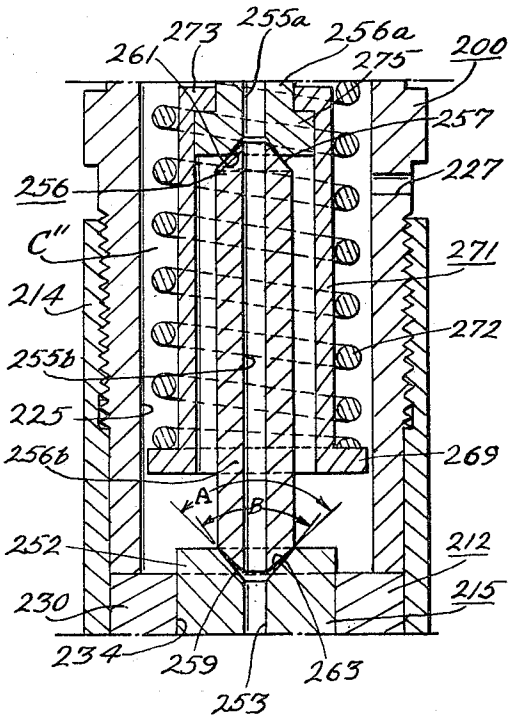


FIG. 7.



INVENTOR:
FRANK DE LUCA

BY Howson & Howson
ATTYS.

United States Patent Office 3,387,790
Patented June 11, 1968

3,387,790

FUEL INJECTION NOZZLE

Frank De Luca, Thompsonville, Conn., assignor to American Bosch Arma Corporation, Springfield, Mass., a corporation of New York

Continuation-in-part of abandoned application Ser. No. 561,489, June 29, 1966. This application Apr. 11, 1967, Ser. No. 633,666
11 Claims. (Cl. 239—453)

ABSTRACT OF THE DISCLOSURE

A fuel injection nozzle assembly comprising a holder, a nozzle mounted at one axial end of the holder having a bore defining a fuel chamber and a valve member mounted for axial movement in the bore of the nozzle. The assembly further includes a plug threadedly mounted in the holder and a stem spaced from the plug to adjust valve lift and spring biasing means in the holder for normally seating the valve in a closed position. The stem and valve have axially extending bores therein so that fuel from the inlet in the holder passes through to the fuel chamber surrounding the valve at the lower end of the nozzle. The tail section of the valve has a pair of angled fuel passageways which connect with the fuel chamber and the axial bore in the tail section of the valve.

This is a continuation-in-part of my prior application Ser. No. 561,489, filed June 29, 1966, for "Fuel Injection Nozzle," now abandoned.

The present invention relates to improvements in fuel injection nozzles.

Some of these fuel injection nozzle assemblies conventionally comprise an elongated holder and a nozzle mounted at one end of the holder, the entire assembly being mounted in an elongated bore in the engine cylinder head to supply fuel to the cylinders of the engine.

In these assemblies, one end of the holder is provided with an inlet adapted to be connected to a suitable fuel supply source and an axial passage is provided in the holder which communicates with a fuel passageway in the nozzle to direct fuel to an annulus in the axial end face of the nozzle confronting the holder. From the annulus, fuel passes through two or more fuel ducts in the nozzle to an enlarged annular sump surrounding a valve member mounted for axial movement in an axial bore in the nozzle. By this arrangement, fuel pressure build up in the sump raises the valve against the bias of a spring in the holder to permit the fuel to pass through spray orifices in the outer free end of the nozzle tip.

Several disadvantages or drawbacks are noted in the conventional type of fuel injection nozzle assembly discussed above. For example, it has been found that it is difficult to reduce the size of these assemblies in terms of cross sectional dimension by reason of the separate axial passage for the fuel, the axial bore for the valve element and chamber for the valve actuating spring. Nozzle assemblies of reduced cross section are desirable to permit more space in the engine cylinder head for larger valves and thus improve the volumetric efficiency of the engine. Furthermore, since these assemblies are comparatively small in size, the construction thereof is difficult due to the precision drilling required to form these fuel passageways or ducts and other internal bores or chambers in the holder and nozzle.

Moreover, the sump tends to trap dirt and foreign particles and is difficult to clean thoroughly. Also, the sump, annulus and seat provide an excess "parasitic" or dead fuel volume which makes it difficult to control fuel injection characteristics. Additionally, in engines employing

the sump-type fuel injection nozzle fuel consumption is high and the engine tends to smoke. Further it has been found that various moving parts of the assembly are extremely sensitive and that conventional spring mountings for the valve element produce side thrusts on the valve member causing sticking and hanging up of the valve. Furthermore, in the conventional fuel injection nozzle assemblies discussed above, flow of fuel is turbulent which again may result in valve sticking and may produce cavitation or erosion.

In accordance with the present invention the fuel passageways or the like in the various elements of the entire assembly are located axially and centrally thereof to permit the entire assembly to be made of a much smaller cross section. More specifically, the fuel injection nozzle assembly of the present invention includes a holder and a nozzle tip mounted at one end of the holder. A tubular plug is mounted in the end of the holder remote from the nozzle, the inner end of which is spaced a predetermined distance from the valve assembly in the closed position of the valve to define a gap controlling valve lift.

The nozzle comprises the usual body portion and an elongated tip or shank, the body portion having a bore in which the valve element slides and a lower bore section defining a fuel chamber. The valve assembly includes an elongated hollow tubular stem mounted in a socket in the tail section of the valve head which is guided adjacent its upper end in the axial bore in the holder. A biasing spring mounted in a spring chamber in the holder circumscribes the stem and serves its normal function to bias the valve assembly to a closed position. The head of the valve is of a streamlined configuration and is connected to the tail section by a reduced neck portion. By this arrangement, fuel enters the fuel injection nozzle assembly through the central opening in the plug, flows through the hollow stem and into the fuel chamber through diametrically opposed angled connecting passages in the tail section of the valve. The head of the valve serves as a venturi in the fuel chamber so that flow through the fuel chamber is laminar. This assembly is comprised of comparatively few parts so that it is easy and economical to make. Furthermore, the valve assembly is guided on either side of the actuating spring to minimize thrust.

With the foregoing in mind, an object of the present invention is to provide a fuel injection nozzle assembly of substantially smaller dimensions particularly in cross section thereby permitting more space in the engine cylinder head for larger valves and thus improve the volumetric efficiency of the engine.

Another object of the present invention is to provide a new and improved fuel injection nozzle assembly with axial high pressure fuel passages for ease of machining and reduction of fuel volume.

Still another object of the present invention is to provide a hollow valve of relatively short length with reduced inertia which facilitates high speed operation.

A still further object of the present invention is to provide a novel fuel injection nozzle assembly wherein the valve is guided at both ends and the actuating spring is positioned between the terminal ends of the valve so as to make the valve less susceptible to side thrust effects from the actuating spring.

Another object of the present invention is to provide a fuel injection nozzle assembly including a valve characterized by novel features of construction and arrangement wherein side thrusts are minimized to insure more reliable functioning of the valve and flow through the assembly is laminar to minimize erosion and cavitation.

A further object of the present invention is to provide a separate fitted assembly of valve and nozzle tip which can be readily serviced or replaced.

These and other objects of the present invention and the various features and details of the operation and construction thereof are hereinafter more fully set forth with reference to the accompanying drawings, wherein:

FIG. 1 is a side elevational view of a fuel injection nozzle assembly in accordance with the present invention;

FIG. 2 is an enlarged sectional view through the assembly showing the same mounted in an opening in an engine cylinder head;

FIG. 3 is an enlarged sectional view similar to FIG. 2 of another embodiment of fuel injection nozzle assembly in accordance with the present invention;

FIG. 4 is an enlarged fragmentary sectional view of the lower terminal end of the assembly with the valve in a closed position;

FIG. 5 is a fragmentary view similar to FIG. 4 showing the valve in an open position;

FIG. 6 is a sectional view similar to FIGS. 2 and 3 of still another embodiment of fuel injection nozzle assembly in accordance with the present invention; and

FIG. 7 is an enlarged sectional view of the lower stem section.

Referring now to the drawings and particularly to FIG. 2 thereof, the fuel injection nozzle assembly includes a nozzle holder **10**, a fuel injection nozzle **12** mounted at the lower axial end of the holder **10** by means of a cap nut **14** for axial movement and a valve assembly **15** mounted in the nozzle. The fuel injection nozzle assembly is adapted to be mounted in an elongated stepped opening **16** in the cylinder head **18** to deliver fuel to the combustion chamber thereof.

The holder **10** is an elongated generally cylindrical member having a fuel inlet **22** at its outer axial end and an axially extending upper bore section **24** which is enlarged adjacent the lower end of the holder as at **25** to define a spring chamber C. An externally threaded plug **26** is mounted in the upper bore section **24** of the holder, the plug **26** having an axially extending central passage **28** through which fuel passes from the inlet **22**. The plug is movable axially in the upper bore section **24** to selectively vary the gap or spacing G between the inner axial end face of the plug **26** and the upper end of the valve assembly to adjust the valve lift. In the present instance the holder is provided with a radial port **27** which communicates with the spring chamber C and serves as a leak-off bypass for fuel leaking into the spring chamber. The leak-off bypass may be connected back to the main fuel supply if desired and in order to seal the entire assembly there is provided an O-ring **29** surrounding the holder above the leak-off bypass.

The nozzle **12** comprises a generally cylindrical body portion **30** and an elongated shank **32** of reduced cross section depending from the body portion. The body portion **30** has an axial bore **34** therein for the valve and a lower bore section **36** of slightly enlarged cross section to define a fuel chamber F. In the present instance a nozzle spray tip **40** is mounted in the lower terminal end of the nozzle which may be press fitted into the enlarged opening in the free end of the nozzle shank, sealed with epoxy resin and spun over for mechanical fastening. The spray tip insert **40** has a conical seat **42** against which the valve seats and a plurality of spray orifices **44** in the outer terminal end of the nose section **46** of the tip through which fuel is delivered to the engine cylinder.

The valve assembly comprises a streamlined head portion **50** having a conical tip **51**, a tail section **52** merging with the head portion in a reduced neck section **54** and an elongated tubular stem **56** mounted in a socket-like opening **58** in the tail section. The stem **56** has an axially extending central fuel channel **62** which at its lower end communicates with a pair of diametrically opposed outwardly diverging outlet holes **66** in the neck of the valve. The stem **56** is secured at its inner end in the socket **58** by means of an epoxy resin type agent and in the seated position of the valve, the opposite outer axial end face

of the stem **56** is spaced from the lower terminal end of the threaded member **26** to provide a gap G determining the valve lift. In the present instance, the head portion **50** has a double conical tapered tip which engages the valve seat in the closed position of the valve and the sidewall of the insert is also tapered to provide an inwardly converging forward section to the fuel chamber conforming generally to the tip.

The valve member is normally biased to the closed position by means of a compression spring **72** in the spring chamber C which abuts the lower end of the chamber at one end and seats on the flange **74** of a collar abutting the tail section of the valve.

In the normal operation of the fuel injection nozzle assembly of the present invention, the spring force of the compression spring **72** and the pressure of the fuel acting on the axial end face of the stem **56** normally maintain the valve member in a closed position where the conical tip **51** engages the valve seat **42**. Now when the fuel pressure builds up to a predetermined amount, the valve member is raised upwardly against the bias of the compression spring **72** due to the area differential between the valve seat diameter D_2 and the stem diameter D_3.

In the present instance, the particular arrangement of the assembly permits the opening and closing of the valve to be controlled very accurately. For example, valve opening pressure P_o is equal to

$$\frac{4F_s}{\pi[(D_1^2-D_2^2)-D_3^2]}$$

valve closing pressure P_c is equal to

$$\frac{4F_s}{\pi(D_1^2-D_3^2)}$$

and compression spring force F_s is equal to

$$\frac{\pi x}{4}P_o(D_1^2-D_2^2-D_3^2)$$

Now assuming a valve opening pressure of 3,000 p.s.i., a valve diameter D_1 of 0.236", a seat diameter D_2 of 0.118" and a stem diameter D_3 of 0.0986", the spring force F_s is 75.6 lbs., and the closing pressure P_c required is 2090 p.s.i. This contrasts with conventional assemblies where the spring load required would be about 100 p.s.i. By the present arrangement, the fuel pressure acting on the area D_3 of the stem reduces the spring load required over conventional ducted nozzles. Further by the present arrangement, by varying the diameter D_3 of the stem, different spring loading and pressure differences may be obtained between the opening and closing pressures.

There is illustrated in FIGS. 3, 4 and 5, another embodiment of fuel injection nozzle in accordance with the present invention. This assembly is generally similar in overall configuration and construction to the embodiment illustrated above and includes a nozzle holder **100**, a fuel injection nozzle **112** mounted at the lower end of the holder by means of a cap nut **114** and a valve assembly **115** mounted in the nozzle.

The nozzle holder **100** has a fuel inlet **122** at its upper axial end and an axially extending upper bore section **124** terminating in an enlarged lower section **125** defining a spring chamber C'. A threaded plug **126** is mounted in the upper bore section **124** and has a central passage **128** through which fuel passes from the inlet **122**.

In the present instance the nozzle **112** is an integral assembly comprising a generally cylindrical body portion **130** and an elongated shank **132** of slightly reduced cross section, the body and shank having axial bore sections **134** and **136** respectively, the bore section **136** being of slightly enlarged cross section and defining a fuel chamber F'. The lower end of the fuel chamber is provided with adjacent conical wall sections **137** and **139**, the lower conical wall section **139** defining a valve seat and merging with a discharge opening **141** in the lower axial end of the nozzle shank.

The valve member **115** comprises a streamlined head portion **150** having a tail section **152** merging with the head portion in a reduced neck section **154** and an elongated hollow tubular stem **156** mounted in a socket-like opening **158** in the tail section, the stem **156** having an axially extending central fuel channel **162** communicating at its lower end with a pair of diametrically opposed outwardly diverging outlet holes **166** in the neck of the valve. The outer axial end face of the stem **156** in the seated section of the valve is spaced from the lower terminal end of the plug **126** to provide a gap G' determining the valve lift. The valve is normally biased to the closed position by means of a compression spring **173** in the spring chamber C' which abuts the lower end of the chamber at one end and seats on the flange **175** of a collar abutting the tail section of the valve.

In the present instance the assembly is a poppet type assembly and to this end the tip of the head portion **150** has a double conical tapered tip **170** which engages the valve seat in the closed position of the valve and a pintle **172** projecting from the tip through the discharge opening **141** in the nozzle shank. As best illustrated in FIGS. 4 and 5, the pintle **172** has a profiled sidewall **174** consisting of an upper frusto conical wall section **176**, a lower frusto conical wall section **178**, which merges with the upper section in a rounded or gently curved neck **180** of narrow width. The upper wall section in the present instance is inclined at a greater angle relative to a plane through the neck **180** perpendicular to the axis of the valve. By this construction when the valve lifts off of its seat as shown in FIG. 5 and the high pressure fuel follows the matching contours of the conical tip and seat of the valve and nozzle shank respectively, the fuel discharges in a wide conical spray. Further by virtue of the short distance between the seat **139** and the straight sided portion of the discharge opening **141**, the flow of fuel is directed inwardly toward the profile portion of the pintle and then reversed as shown to issue a wide spray up to 180°.

Further, in the operation of the valve due to the particular configuration of the fuel ducts and passageways and the streamlined configuration of the valve head, flow through the fuel injection nozzle assembly may be described as laminar thereby minimizing erosion and cavitation.

Moreover, by elimination of the annulus and sump, areas that tend to trap dirt and foreign particles which are difficult to clean are eliminated. By the present arrangement, fuel injection characteristics may be controlled more accurately by minimizing parasitic or dead fuel volume. Also by the particular spring mounting between the extreme ends of the valve member, deleterious side thrust due to the spring are minimized and accordingly, the valve has less tendency to stick or hang up. Lastly, the assembly of the present invention is extremely economical to manufacture and with this design reduction of the nozzle diameter and miniaturization are possible.

There is illustrated in FIG. 6 still another embodiment of fuel injection nozzle in accordance with the present invention. This assembly is generally similar in overall construction to the previous embodiment and includes a nozzle holder **200**, a fuel injection nozzle **212** positioned at the lower end of the holder by means of a cap nut **214** and a valve assembly **215** mounted interiorly of the nozzle and adapted for axial movement therein between an open position and a closed position.

The holder **200** is an elongated generally cylindrical member having a fuel inlet **222** at its outer axial end and an axially extending upper bore section **224** which is enlarged adjacent the lower end of the holder as at **225** to define a spring chamber C''.

An externally threaded plug **226** is mounted in the upper bore section **224** of the holder, the plug **226** having an axially extending central passage **228** through which fuel passes from the inlet **222**. The plug is movable axially in the upper bore section **224** to selectively vary the gap or spacing G'' between the inner axial end face of the plug **226** and the upper end of the valve assembly to adjust the valve lift. In the present instance the holder is provided with a radial port **227** which communicates with the spring chamber C'' and serves as a leakoff bypass for fuel leaking into the spring chamber. The leakoff bypass may be connected back to the main fuel supply if desired.

The nozzle **212** comprises a generally cylindrical body portion **230** and an elongated shank **232** of reduced cross section depending from the body portion. The body portion **230** has an axial bore **234** therein for the valve and a lower bore section **236** of slightly enlarged cross section to define a fuel chamber F''. The lower terminal end of the nozzle body portion **230** has a conical seat **252** against which the valve seats and a plurality of spray orifices **244** in the tip of the nozzle shank **237** through which fuel is delivered to an engine cylinder.

The valve assembly comprises a streamlined head portion **250** having a conical tip **251**, and a tail section **252** merging with the conical tip in a reduced neck section **254**. The tail section has a central axial bore **253** which at its lower end merges with a pair of diametrically opposed, outwardly diverging outlet holes **266** in the neck of the valve. As illustrated, the head portion **250** has a double conical tapered tip which engages the valve seat in the closed position of the valve and the interior sidewall of the valve body adjacent the tip is also tapered to provide an inwardly converging forward section to the fuel chamber F'' conforming generally to the tip.

In the present instance, the valve assembly includes an elongated tubular stem assembly **256** comprising an upper section **256*a*** and a lower section **256*b***, the upper stem section **256*a*** being mounted in the central passageway in the holder having its upper end spaced from the plug **226** to provide a gap or spacing G'' determining the valve lift. The stem sections as illustrated are elongated hollow tubular members having axial bores **255*a*** and **255*b*** which communicate with the central opening in the plug **226** and the bore in the tail section to permit flow of fuel from the source to the fuel chamber F''. As in the previously described embodiments, the plug **226** is adjustable axially so that the valve lift may be selectively varied. The lower stem section **256*b*** has tapered conical terminal ends **257** and **259** which nest in conical seats **261** in the upper stem section **256*a*** and a conical seat **263** in the axial end face of the tail section of the valve. The coil spring **272** in the spring chamber C'' at one end engages shims **267** mounted in the upper end of the spring chamber and at its opposite end engages a radial flange **269** on the lower end of the sleeve **271**, the sleeve **271** having an inwardly directed flange **273** overlying the enlarged lower end **275** of the upper stem section **256*a***.

In the normal operation of the fuel injection nozzle assembly described above, the spring forces of the compression spring **272** and the pressure of the fuel acting on the axial end face of the upper stem assembly **256*a*** normally maintain the valve member in a closed position wherein the conical tip **251** engages the valve seat **252**. Now when the fuel pressure builds up to a predetermined amount, the valve member is raised upwardly against the bias of the compression spring due to the area of differential of the valve seat diameter D_6 and the stem diameter D_7.

In the present instance the two-piece stem assembly **256*a*** and **256*b*** provides flexibility and eliminates excessive side thrusts on the valve. Further, in order to eliminate leakage of high pressure fuel at the juncture of the lower stem section **256*b*** with the upper stem section and valve, the mating angular surfaces have a different angle of taper so that the parts seat on the ouside diameter. Preferably the included angle A on the ends of the lower stem section **256*b*** is greater than the counter-sink angle on the seats in the upper stem section and valve. For ex-

ample, if the included angle A is 90°, then the countersink angles B for the seat in the tail section and the seat on the lower end of the stem assembly are between 80–85°.

While particular embodiments of the present invention have been illustrated and described herein, it is not intended to limit the invention and changes and modifications may be made therein within the scope of the following claims.

I claim:

1. A fuel injection nozzle assembly comprising an elongated holder, a nozzle mounted at one axial end of the holder, means defining a first axial bore in the nozzle defining a fuel chamber, valve member means mounted for axial movement in said bore between open and closed positions, a fuel inlet in the axial end of said holder opposite said one axial end, means defining a second axial bore in said holder communicating with said inlet, said valve member including an elongated stem engaging in said second axial bore, said stem having a central fuel passage communicating at its inner end with a pair of angled fuel passageways in said valve member which in turn communicates with said fuel chamber.

2. A fuel injection nozzle assembly as claimed in claim **1** including a plug mounted in said second axial bore having its inner end normally spaced from an axial end of said stem providing a gap determining valve lift.

3. A fuel injection nozzle as claimed in claim **2** wherein said plug is movable axially in said bore whereby the gap may be varied selectively to vary valve lift.

4. A fuel injection nozzle assembly as claimed in claim **1** including an enlarged lower bore section in said one end of the holder defining a spring chamber and including a spring in said chamber circumscribing said stem.

5. A fuel injection nozzle assembly as claimed in claim **1**, wherein said valve member has a streamlined head portion including a conical tip, a tail section merging with the head portion in a reduced neck section.

6. A fuel injection nozzle assembly as claimed in claim **1** including a tip insert mounted in the axial bore in the free end of said nozzle.

7. In a fuel injection nozzle assembly including a holder having a fuel inlet, a nozzle having a first axial bore defining a fuel chamber, a discharge opening in one axial end of the nozzle and a valve seat adjacent the discharge opening, valve member means mounted in said fuel chamber having a streamlined head portion including a conical tapered tip, a pintle projecting from the tip, said pintle consisting of an upper frusto-conical wall section, a lower frusto conical wall section which merges with the upper wall section in a rounded neck of reduced cross section, means defining a second axial bore in said holder communicating with said inlet, said valve member including an elongated stem engaging in said second axial bore, said stem having a central fuel passage communicating at one end with said inlet and at said opposite end with said fuel passage in said valve member which in turn communicates with said fuel chamber, said valve member adapted for axial movement in said first axial bore between a closed position wherein the tip engages the nozzle seat and an open position wherein the tip is spaced from the seat whereby fuel discharges in a wide conical spray.

8. A fuel injection nozzle assembly comprising an elongated holder, a nozzle mounted at one axial end of the holder, means defining a first axial bore in the nozzle defining a fuel chamber, valve member means mounted for axial movement in said bore between open and closed positions, a fuel inlet in the axial end of said holder opposite said one axial end, means defining a second axial bore in said holder communicating with said inlet, said valve member including an elongated stem engaging in said second axial bore, said stem having a central fuel passage communicating at one end with said inlet and at its opposite end with a fuel passage in said valve member which in turn communicates with said fuel chamber.

9. A fuel injection nozzle assembly as claimed in claim **8** wherein said stem comprises an upper stem section engaging in said second axial bore and a lower stem section at one end engaging the upper stem section and at its opposite end engaging the upper axial end face of the valve member.

10. A fuel injection nozzle assembly as claimed in claim **9** wherein said lower stem section has tapered conical terminal ends which engage in conical seats in the upper stem section and valve member respectively.

11. A fuel injection nozzle assembly as claimed in claim **10** wherein the angle of taper at the terminal ends of the lower stem section is greater than the included angle of said conical seats.

References Cited

UNITED STATES PATENTS

3,224,684	12/1965	Roosa	239—533
3,244,377	4/1966	Roosa	239—533
3,255,974	6/1966	Roosa	239—533

FOREIGN PATENTS

1,121,065	4/1956	France.
592,519	2/1934	Germany.
617,795	2/1949	Great Britain.
746,785	3/1956	Great Britain.

EVERETT W. KIRBY, *Primary Examiner.*