

July 28, 1942.

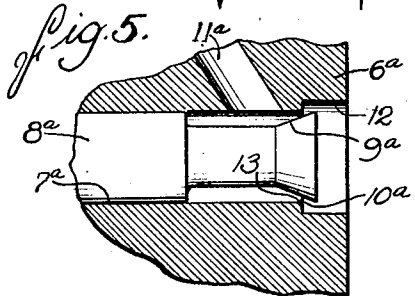
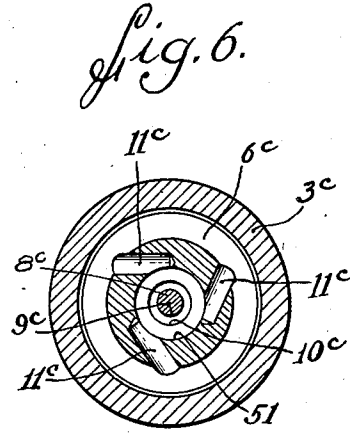
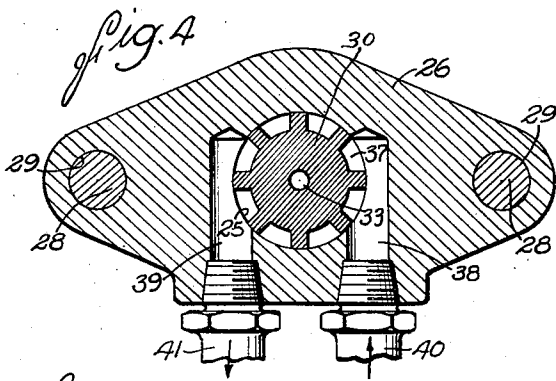
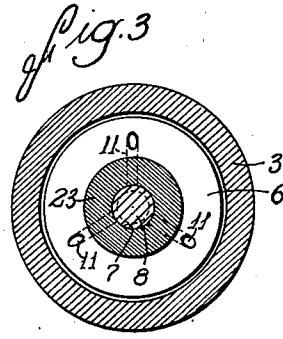
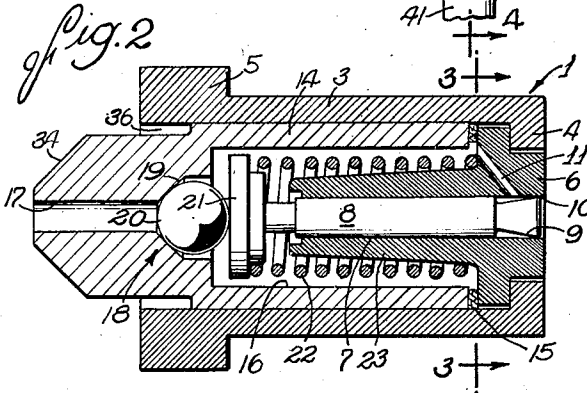
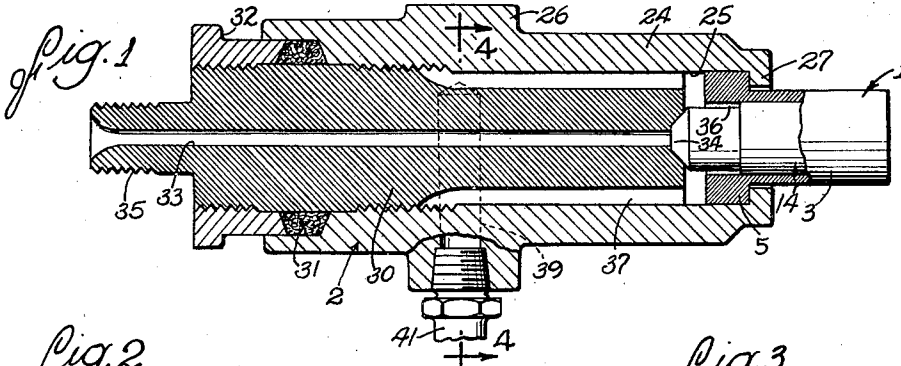
J. F. HOFFER

2,291,218

NOZZLE

Filed July 6, 1937

2 Sheets-Sheet 1



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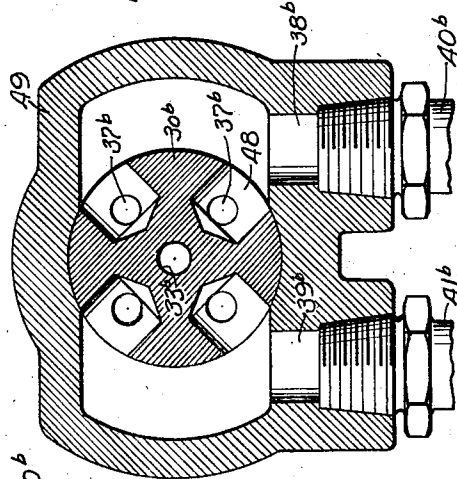
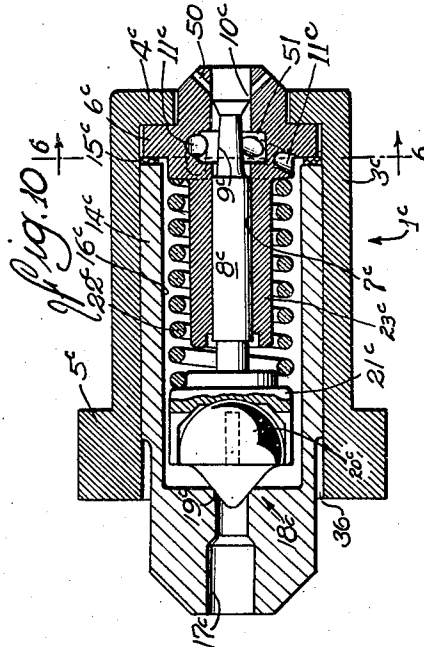
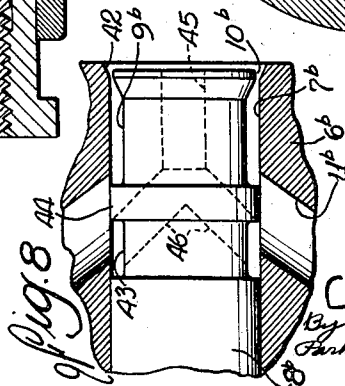
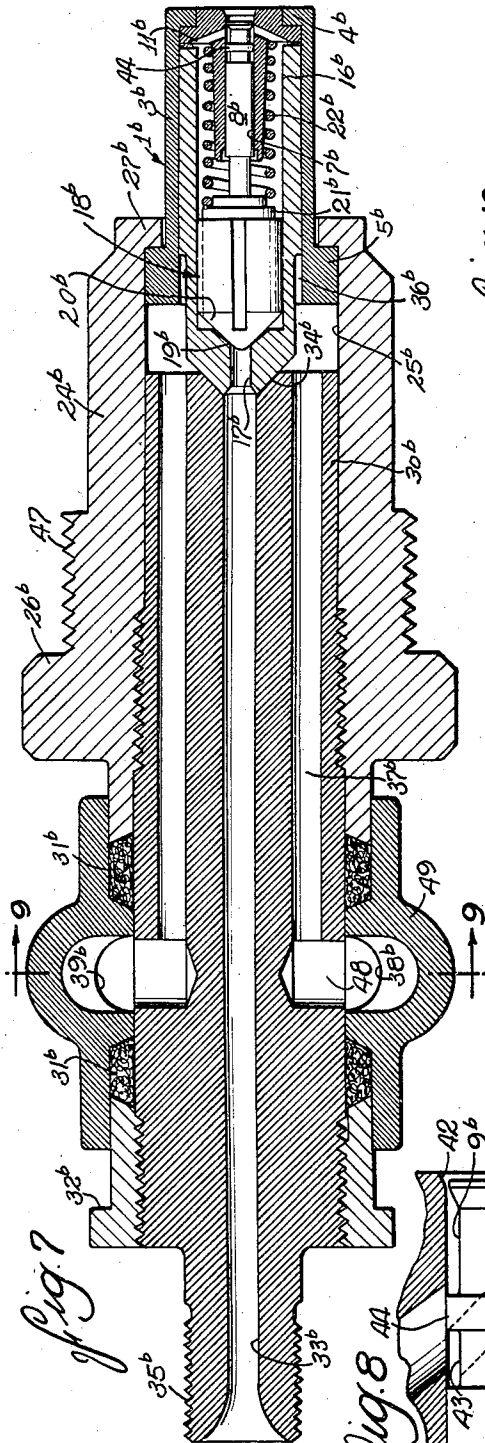
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2,291,218

NOZZLE

Filed July 6, 1937

2 Sheets-Sheet 2



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2,291,218

NOZZLE

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Application July 6, 1937, Serial No. 152,127

21 Claims. (Cl. 299—107.6)

The present invention relates to improvements in nozzles adapted particularly for delivering timed metered injections of liquid fuel in connection with the operation of internal combustion engines.

One of the objects of the invention is to provide a novel fuel injection nozzle of the pintle type which will open and close with a popping action, thereby preventing dribbling, dripping or bleeding of the fuel.

Another object is to provide a new and improved fuel injection nozzle having an outwardly opening pintle which defines a discharge orifice, and which is graduated in form to provide in the opening movement a progressive increase in the flow area of the orifice.

A further object of the invention is to provide a novel fuel injection nozzle having a spring-seated inlet valve with a seat defining a fuel lifting pressure area, and having a discharge means including a pintle movable with the valve and defining a supplemental fuel lifting pressure area larger than said first mentioned area and effective after initial valve opening to accelerate the continued opening movement.

Other objects reside in a new and improved fuel injection nozzle of the outwardly opening pintle type having discharge means adapted to deliver a plurality of fuel jets of selective spray characteristics.

Still another object is to provide a novel fuel injection nozzle having means for cooling the discharge tip.

Further objects and advantages will become apparent as the description proceeds.

In the accompanying drawings, Figure 1 is a longitudinal sectional view on an enlarged scale of one form of a nozzle embodying features of the present invention.

Fig. 2 is an axial sectional view on a still larger scale of the discharge tip of the nozzle.

Fig. 3 is a transverse sectional view taken along line 3—3 of Fig. 2.

Fig. 4 is a transverse sectional view taken along line 4—4 of Fig. 1.

Fig. 5 is a fragmentary axial sectional view of a modified form of discharge means.

Fig. 6 is a fragmentary transverse sectional view taken long line 6—6 of Fig. 10.

Fig. 7 is a longitudinal sectional view on an enlarged scale of a modified form of nozzle.

Fig. 8 is an enlarged fragmentary sectional view of the discharge means shown in Fig. 7, but with the parts in open position.

Fig. 9 is a transverse sectional view taken along line 9—9 of Fig. 7.

Fig. 10 is a longitudinal sectional view of still another form of nozzle tip.

While the invention is susceptible of various modifications and alternative constructions, I have shown in the drawings and will herein describe in detail the preferred embodiment, but it is to be understood that I do not thereby intend to limit the invention to the specific form disclosed, but intend to cover all modifications and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

Referring more particularly to the drawings, one form of fuel injection nozzle embodying features of the present invention (Fig. 1) comprises a replaceable nozzle unit or tip 1 removably mounted in a holder 2. It will be understood that the nozzle tip 1 is adapted to be clamped or secured by means of the holder 2 to the engine (not shown) at the desired point of injection.

The nozzle tip 1 has a suitable body or housing 3. Preferably, the body 3 is in the form of a tubular shell having an inner peripheral flange 4 at the discharge end and an external peripheral mounting flange 5 at the base end.

Removably seated against the inside of the flange 4 and extending through the central opening defined thereby to the outer end face of the body 3 is an orifice head 6. The present nozzle is of the pintle type, and hence the orifice head 6 is formed with a central discharge passage 7 in which a pintle 8 is slidably disposed. The passage 7 and the pintle 8 coact to define a discharge orifice means which has the desired fuel discharge characteristics for proper atomization and penetration. By selective variation in the form of the passage 7 or the pintle 8 or both different spray patterns and characteristics may be obtained as desired to best suit different engine requirements. In the present instance, the discharge passage 7 is an axial bore of constant diameter, and the pintle 8 consists of a cylindrical stem formed in the outer end portion with a peripheral groove or undercut 9 to define a single annular discharge orifice 10. This undercut is suitably shaped to provide a graduated orifice discharge. In Fig. 2, the undercut 9 is conically tapered inwardly, and the pintle 8 is movable outwardly in the opening movement of the nozzle to obtain a progressively increasing orifice area. A plurality of fuel supply passages 11, three for example, open from the interior of the body 3 through the orifice head 6 to the bore 7 in con-

stant communication with the undercut 9. In Fig. 2, these passages are radial so that the annular fuel jet issuing from the orifice 10 is non-centrifugal.

Fig. 5 illustrates a modified construction in which the orifice head 6^a is formed with a short counterbore 12 at the outer end of the axial discharge bore 7^a, and in which the undercut 9^a of the pintle 8^a is partly cylindrical and partly conical or tapered. Radial fuel supply passages 11^a open to the bore 7^a inwardly of the counterbore 12. The pintle 8^a coacts with the outer edge 13 of the bore 7^a to define an annular discharge orifice 10^a, the effective area of which during the nozzle opening movement will increase initially by reason of the tapered portion of the undercut 9^a, and then will remain constant by reason of the cylindrical portion of the undercut. The tapered portion of the undercut 9^a when in cooperative relation with the edge 13 acts to direct the annular fuel jet issuing from the orifice 10^a against the surface of the counterbore 12. The issuing jet is thereby deflected and caused to converge into a narrow angle spray. Because of this action, the angle of the pintle taper can be made steeper than in Fig. 1 without increasing the dispersion angle of the spray, thereby resulting in a more rapid opening of the orifice 10^a and permitting the use of a shorter pintle travel for a given opening.

The orifice head 6 is held in position by a cylindrical valve body 14 snugly fitted into the shell 3. A suitable gasket 15 is interposed between the orifice head 6 and the valve body 14 to provide a fluid-tight seal. The inner end of the valve body 14 is formed with an axial bore 16 defining a chamber in communication with the passages 11. The other end is formed with an axial pressure inlet passage 17 adapted to be connected through the holder 2 and a conduit (not shown) to a suitable source of fuel under pressure, such, for example, as a metering fuel pump (not shown).

The supply of fuel from the inlet passage 17 to the chamber 16 is under the control of a spring-seated valve indicated generally at 18 which may be of any suitable form or character. In the present instance, the valve 18 comprises a conical annular seat 19 formed in the body 14 at the discharge end of the passage 17. A movable valve member 20 is disposed within the body 14 for concentric engagement with the seat 19, and when seated has an effective transverse area exposed to the fuel pressure in the passage 17. This area is substantially equal to the transverse area of the passage 17 and is hereinafter referred to as the valve opening pressure area. The valve member 20 is shown in the form of a ball supported by a circular retainer head 21 on the inner end of the pintle 8. A coil compression spring 22 is seated at opposite ends against the orifice head 6 and the retainer head 21, and tends to close the valve 18 with a predetermined spring pressure, and as an incident thereto to retract the pintle 8 into closed position. Preferably, the orifice head 6 is provided with an axial sleeve 23 which serves to guide the pintle 8 and to center the fixed end of the spring 22. It will be evident that the inner end of the axial sleeve 23 would act as a stop upon engagement of the retainer head 21 to limit the maximum height of rise of the fuel inlet valve and also to limit the maximum extent of outward movement of the pintle 8.

To cause the valve 18 to open with an increased acceleration or popping action, the effective area of the pintle 8, which in closed position is the free end area at the orifice 10, is made larger than the valve opening area. The popping action may be controlled by selective variation in the relative effective diameters of the seat 19 and the pintle 8.

In operation, fuel under pressure is supplied to the passage 17 from the pump or other suitable source. When the fuel pressure acting on the valve opening area exerts a force sufficient to overcome the pressure of the spring 22, the valve 18 will open to permit the flow of fuel through the chamber 16 and the passages 11 to the orifice 10.

The valve 18 will be moved into a position of equilibrium in which the hydraulic force balances the pressure of the spring 22. As the fuel pressure is increased, the hydraulic force will be increased to effect a greater spring compression and consequently a greater pintle movement. As the valve starts to open, fuel pressure is built up in the chamber 16 by reason of the orifice restriction, and becomes immediately effective on the relatively larger pintle area to accelerate the opening movement. Hence, the valve member 20 is moved out of close proximity with the seat 19 with a popping action.

The fuel is discharged from the orifice in the form of an annular spray. As the pintle 8 is moved outwardly, the flow area of the orifice 10 is progressively increased.

When the delivery from the source ceases, the pressure in the passage 17 and the chamber 16 will drop to a point at which the spring 22 will again close the valve 18, thereby shutting off the flow of fuel and the return flow of gases from the combustion space. The valve closing pressure will be lower than the valve opening pressure as determined by the difference in area of the valve seat 19 and the pintle 8. It will be understood that in the valve closing movement, the flow area of the orifice 10 is progressively decreased.

The holder 2 serves to support the nozzle tip 1 and to connect the latter to the fuel source. In the form illustrated in Fig. 1, the holder 2 comprises an outer body or housing 24. Preferably, the holder body 24 consists of an elongated generally tubular shell having a longitudinal bore 25 and an external peripheral mounting flange 26. One end of the body 24 is formed with an inner peripheral flange 27 for holding the nozzle tip 1, and is adapted to be clamped to the engine by means of bolts 28 extending through suitable holes 29 in the flange 27.

The nozzle tip 1 is removably mounted in the holder body 24 by engagement of the flange 5 with the flange 27, and projects through the latter to discharge into the combustion chamber of the engine. An elongated cylindrical connecting member 30 is suitably secured in the bore 25 to clamp the nozzle tip 1 in position. In the present instance, the member 30 is threaded into the body 24 to engage the projecting end of the valve body 14. A suitable packing 31 compressed by a nut 32 on the outer end of the member 30 serves to seal the outer end of the holder body 24. Opening axially through the member 30 is a passage 33 connecting with the passage 17, and flared at the inner end for engagement with a complementary taper 34 on the valve body 14 to provide a high pressure seal. The outer end of the passage 33 opens through a threaded nipple 35 on the mem-

ber 30 for a tight connection with a conduit (not shown) leading from the fuel source.

The nozzle is provided with means for effecting cooling, by direct liquid contact, of the nozzle tip 1, so as to materially reduce any objectionable effects that high temperatures might otherwise have on the orifice body 6, the pintle 8 and the adjacent fuel. More particularly, the connecting end of the valve body 14 is peripherally undercut to provide an annular space 36 in the base of the nozzle tip 1, and the holder 2 is formed with passages for circulating a cooling medium, such for example as water, oil or other selected fluids, to and from this space. In the present instance, the inner end portion of the connecting member 30 is formed externally with a plurality of uniformly peripherally spaced longitudinal grooves 37 which coact with the surface of the bore 25 to define cooling fluid passages. The inner ends of the passages 37 open to the space between the nozzle tip body 3 and the member 30, and are therefore in communication with the space 36. Two transverse bores 38 and 39 are formed in the holder body 24, preferably in the plane of the flange 26, and respectively intersect diametrically opposite sides of the bore 25 for communication with the outer ends of the adjacent passages 37. Inlet and outlet coolant tubes 40 and 41 are suitably connected respectively to the bores 38 and 39.

It will be evident that the cooling medium is circulated constantly through the space 36 for heat absorbing contact with the nozzle tip body 3 and the valve body 14. The entering fluid flows inwardly along the passages 37 opening from the bore 38, and the heated fluid leaves through the opposite passages opening to the bore 39. Since the passages 37 are provided in closely and uniformly spaced relation throughout the periphery of the member 30, proper registration with the bores 38 and 39 is always obtained regardless of position.

The features of the invention are also applicable to nozzles having orifice means for discharging a plurality of jets of various forms and in various sequences. Figs. 7 to 9 illustrate a modified form of nozzle providing a hollow annular jet over the entire range of valve movement and a central solid jet or core over the wide open portion of the range. In this form, the change in spray characteristics is obtained by a modification of the pintle construction. In other respects, the nozzle tip is closely like that in Fig. 1, and hence the corresponding parts are identified by the same reference numerals plus the letter b.

The operative end of the pintle 8^b is formed with an annular groove or peripheral undercut 9^b always in communication with the passages 11^b. The inner portion of the undercut 9^b is cylindrical, and the outer portion has a short taper and coacts with the bore 7^b to provide an annular orifice 10^b. The pintle 8^b never projects beyond the outer end face of the orifice head 6^b, but the outer end of the bore 7^b is chamfered as indicated at 42 to increase the flow area of the orifice 10^b as the valve 18^b moves toward full open position.

A second peripheral groove or undercut 43 is formed in the pintle 8^b inwardly of the undercut 9^b, and is separated from the latter by an intermediate rib 44 in close sliding engagement with the bore 7^b. A plain hole orifice 45 opens axially to the outer end of the pintle 8^b, and is connected at the inner end through a plurality of inclined holes 46 to the undercut 43.

When the pintle 8^b is in closed position (see

Fig. 7), the rib 44 cuts off communication between the passages 11^b and the undercut 43. During the initial opening movement only a thin annular spray, having a low rate of flow and penetrating power, will issue from the orifice 10^b. Upon continued movement, in response to a sufficient pressure increase in the chamber 16^b, the undercut 43 will open to the passages 11^b (see Fig. 8). Thereupon, a solid jet, enveloped by the annular spray and sufficiently large to provide an optimum of penetrating power, also will issue from the control orifice 45. As full open position is approached, the annular jet is enlarged by reason of the chamfer 42. It will be understood that at very low rates of injection, for example, when the engine is being cranked or slowly idled, the pintle 8^b may not open sufficiently to discharge the central jet.

The valve member 20^b in this nozzle is shown in the form of a cylindrical plug which is seated against the head 21^b and is tapered at the opposite end for engagement with the seat 19^b, and which is slidable in the bore 16^b and is longitudinally fluted to permit the free passage of fuel.

The nozzle illustrated in Figs. 7 to 9 also embodies a modified form of holder 2^b in which the outer body 24^b has a threaded portion 47 adapted to be screwed into the combustion chamber. The connection member 30^b, with the axial passage 33^b opening from the nipple 35^b, engages the tapered end 34^b of the valve body 14^b to clamp the flange 5^b against the flange 27^b in the same manner as in Fig. 1. In this instance, the coolant passages 37^b are defined by a plurality of longitudinal bores, for example, four, which are uniformly spaced about the central fuel passage 33^b, and which open at their inner ends to the space 36^b. The outer ends of the passages 37^b open through radial holes 48 to the periphery of the member 30^b for communication with inlet and outlet ports 38^b and 39^b in an encircling coolant manifold 49. In assembly, the manifold 49 is turned into the proper angular position to establish the inlet and outlet connections, and is then clamped tightly in position by the nut 32^b. Suitable packing 31^b is inserted between the member 30^b and the ends of the manifold 49 to obtain a fluid tight seal.

Still another form of nozzle tip 1^c, adapted to be mounted in either of the holders 2 and 2^b, is illustrated in Fig. 10. In this form, the fuel is discharged initially in an annular jet and then also in a plurality of solid jets in any desired directions. The nozzle tip generally is similar to that in Fig. 1, and hence corresponding parts are identified by the same reference numerals plus the letter c.

The orifice body 6^c projects beyond the end face of the flange 4^c, and is formed with a plurality of plain hole orifices 50 opening to the bore 7^c adjacent the outlet. The number, size and angle of the orifices 50 may be varied in accordance with the requirements of the combustion chamber. In the present instance, the orifices 50 are inclined to obtain widely diverging jets.

The pintle 8^c has an undercut 9^c of which the outer end portion is tapered and coacts with the bore 7^c to define the annular orifice 10^c. The passages 11^c open to an annulus 51 in the bore 7^c and always in registration with the undercut 9^c, and are tangential to obtain a cen-

trifugal annular spray having an angle of divergence approximately the same as that of the solid jets.

The taper on the end of the pintle 8° is short so as not to throttle the fuel entering the orifices 50, and yet is sufficiently long to prevent an undue enlargement of the orifice 10° while moving across the orifices 50.

In operation, the pintle 8°, when in closed position and during the initial portion of the opening movement, is located inwardly of the orifices 50. Therefore, the fuel is discharged initially in a single annular jet. After a predetermined outward movement depending on the length of the pintle 8°, the orifices 50 are opened to the undercut 9°, and discharge a plurality of supplemental solid jets externally of the central conical jet.

I claim as my invention:

1. In a fuel injection nozzle, in combination, a nozzle tip having an outer casing with fuel inlet means at one end, an orifice head at the other end of said casing and having an axial discharge bore chamfered at the outer edge and in communication with said inlet means, a pintle reciprocable in said bore and having two longitudinally spaced peripheral undercuts, the outermost undercut being always in communication with said inlet means and having a tapered portion coacting with said bore and the chamfered end thereof to define an annular orifice increasing progressively in size upon outward movement of said pintle, an axial plain hole orifice opening to the end of said pintle and communicating with the innermost undercut, said innermost undercut being movable into communication with said inlet means after a predetermined outward movement of said pintle, spring means tending to retract said pintle into position to interrupt communication between said inlet means and said innermost undercut, and means responsive to the pressure of the fuel for moving said pintle outwardly.

2. In a fuel injection nozzle, in combination, a nozzle tip having an outer casing with fuel inlet means, an orifice head on said casing and having a discharge bore in communication with said inlet means, a pintle reciprocable in said bore and having two longitudinally spaced peripheral undercuts, the outermost undercut being always in communication with said inlet means and having a portion coacting with said bore to define an annular orifice, an orifice opening to the end of said pintle and communicating with the innermost undercut, said innermost undercut being movable into communication with said inlet means after a predetermined outward movement of said pintle, spring means tending to retract said pintle into position to interrupt communication between said inlet means and said innermost undercut, and means responsive to the pressure of the fuel for moving said pintle outwardly.

3. In a fuel injection nozzle, in combination, a nozzle tip having an outer casing with fuel inlet means, an orifice head on said casing and having a discharge passage in communication with said inlet means, a pintle reciprocable in said passage and having two longitudinally spaced undercuts adapted for communication with said inlet means, one undercut having a portion coacting with said bore to define an annular orifice, an orifice opening to the end of said pintle and communicating with the other undercut, spring means tending to move said pintle in one direc-

tion, and means responsive to the pressure of the fuel for moving said pintle in the other direction.

4. In a fuel injection nozzle, in combination, a nozzle tip having a casing with fuel inlet means and a discharge passage in communication with said inlet means, an outwardly opening pintle reciprocable in said passage and having undercut means adapted for communication with said inlet means and having a uniformly tapered portion coacting with said passage to define an annular orifice communicating with said undercut means and increasing progressively in size upon outward movement of said pintle, an orifice opening to the end of said pintle and communicating with said undercut means, spring means tending to retract said pintle, and means responsive to the pressure of the fuel for moving said pintle outwardly.

5. In a fuel injection nozzle, in combination, a nozzle tip having a casing with fuel inlet means and a discharge passage in communication with said inlet means, a pintle reciprocable in said passage and upon movement in one direction coacting therewith to define a discharge orifice of progressively increasing flow area, a supplemental discharge opening adapted to be connected by said pintle to said inlet means upon movement of said pintle into a predetermined position, spring means tending to move said pintle in one direction, and means responsive to the pressure of the fuel for moving said pintle in the other direction.

6. In a fuel injection nozzle, in combination, a nozzle tip having a casing with fuel inlet means and a discharge passage, means establishing communication between said inlet means and said passage and adapted to impart a swirling motion to the fuel upon entering said passage, a pintle reciprocable in said passage, and upon movement in one direction coacting therewith to define a discharge orifice, a supplemental discharge opening adapted to be connected by said pintle to said inlet means upon movement of said pintle into a predetermined position, spring means tending to move said pintle in one direction, and means responsive to the pressure of the fuel for moving said pintle in the other direction.

7. In a fuel injection nozzle, in combination, a casing having fuel inlet means, an orifice head on one end of said casing and having an axial discharge bore open to said inlet means, a plurality of diverging plain hole orifices opening from said bore through said orifice head to the end of said casing, a pintle reciprocable in said bore and having an undercut open to said inlet means and with a tapered end portion coacting with said bore to define an annular discharge orifice and movable across said plain hole orifices to connect the latter with said inlet means after a predetermined outward movement, spring means tending to retract said pintle into closed position inwardly of said plain hole orifices, and means responsive to the fuel pressure for moving said pintle outwardly.

8. In a fuel injection nozzle, in combination, a casing having fuel inlet means, an orifice head on one end of said casing and having a discharge passage open to said inlet means and a discharge orifice opening from said passage, a pintle reciprocable in said passage and coacting with said passage to define an annular discharge orifice and movable across said first mentioned orifice to connect the latter with said inlet means after a predetermined outward movement, spring means tending to retract said pintle into closed

position inwardly of said discharge orifice, and means responsive to the fuel pressure for moving said pintle outwardly.

9. In a fuel injection nozzle, in combination, a casing, a removable orifice head mounted in one end of said casing and having an axial discharge bore and a plurality of down-flow passages opening from said casing tangentially to said bore and a discharge port opening from said bore, an inwardly extending axial sleeve on said head, a valve body seated in the other end of said casing against said head and having a chamber open to said passages and an axial inlet passage opening to said chamber, an annular valve seat at the discharge end of said inlet passage, a valve member adapted for engagement with said seat and when seated having an opening pressure area defined by said seat and exposed to the fuel in said inlet passage, a stem reciprocable in said sleeve and having a retainer head in said chamber for supporting said valve member for self-centering engagement with said seat, compression spring means between said orifice head and said retainer head and encircling said sleeve for urging said valve member toward closed position, and a pintle on the outer end of said stem and coacting with said bore in all positions of said valve to define an annular restricted discharge orifice, said pintle having a peripheral inwardly tapering straight line undercut in communication with said down-flow passages and upon outward movement serving to connect said port to said undercut.

10. In a fuel injection nozzle, in combination, a casing having an outlet passage, spring seated valve means for controlling the supply of fuel under pressure to said passage, and a pintle associated with said valve means for movement therewith and extending reciprocally into said passage to define an annular restricted outlet orifice open in all positions of said pintle, said pintle being movable outwardly upon opening of said valve means and throughout the outward movement coacting with said passage to increase the radial flow area of said orifice, said pintle having an effective differential pressure area effective when exposed to the fuel pressure upon the initial increment of valve opening to accelerate the continued initial opening movement of said valve.

11. In a fuel injection nozzle, in combination, a casing having a chamber, a fuel inlet passage opening to said chamber, and an outlet passage opening from said chamber, an outwardly opening spring-seated valve controlling said inlet passage and having a seat defining a valve opening pressure area, and a cylindrical pintle movable with said valve and having an undercut portion adjacent the end coacting with said discharge passage in all positions of said valve and to define during fuel discharge a restricted fuel discharge injection orifice opening directly to the exterior of said nozzle, said pintle having an effective differential pressure area larger than said first mentioned area in all positions of said valve and exposed to the pressure in said chamber and acting in a direction to lift said valve during fuel discharge.

12. In a fuel injection nozzle, in combination, a casing having a chamber with an outlet bore and an inlet bore, a pintle reciprocable in said outlet bore and having an inwardly tapering end coacting with said outlet bore during fuel discharge to define an annular restricted injection orifice increasing progressively in flow area upon

outward movement of said pintle into full open position, a valve for controlling said inlet bore and having an annular seat defining an opening pressure area and a valve member movable with said pintle, and compression spring means for urging said valve member toward said seat and retracting said pintle in said outlet bore, said pintle having a differential lifting pressure area larger than said first mentioned area and exposed in said chamber to act in opposition to said spring means throughout the movement of said valve member.

13. A fuel injection nozzle comprising, in combination, a casing having an inlet passage and an outlet cylindrical passage for discharging fuel therefrom, valve means for controlling communication between said passages and having a seat opening inwardly to said inlet passage and defining an opening pressure area, an outwardly opening valve member for coacting with said seat, and compression spring means tending to move said valve member toward and into engagement with said seat, and a pintle outwardly of and movable longitudinally as a unit with said valve member and having an inwardly axially tapering outer end portion reciprocable in said outlet passage and coacting therewith during fuel discharge to define an annular restricted fuel-atomizing discharge orifice symmetrical about the periphery and increasing progressively in effective radial flow area upon outward movement of said pintle, the outer end face of said pintle being substantially in the transverse plane of the outer end of said outlet passage when said valve means is closed, said pintle constituting a differential piston having an effective piston area larger than said opening pressure area adapted to be exposed to the fuel pressure in said casing inwardly of said orifice in the initial opening movement of said valve means and acting in opposition to said spring means to effect opening and closing of said valve means with a popping action.

14. A fuel injection nozzle comprising, in combination, a casing having an inlet passage and an outlet passage for discharging fuel therefrom, valve means for controlling communication between said passages and having a seat opening inwardly to said inlet passage and defining an opening pressure area, an outwardly opening valve member, and compression spring means tending to move said valve member toward and into engagement with said seat, and a pintle movable longitudinally as a unit with said valve member and having an outer end portion reciprocable in said outlet passage and coacting therewith during fuel discharge to define an annular restricted fuel-atomizing injection discharge orifice, said pintle having an outer end area outwardly of said orifice exposed to the pressure externally of said nozzle and an inner end area inwardly of said orifice to constitute a differential piston having an effective piston area larger than said opening pressure area adapted to be exposed to the fuel pressure in said casing inwardly of said orifice while said valve means is open and acting in opposition to said spring means to effect opening and closing of said valve means with a popping action.

15. In a fuel injection nozzle, in combination, a casing, an orifice head at one end of said casing and having a central discharge bore and a down-flow passage opening from said casing to said bore, an inwardly extending sleeve on said head, a valve body in the other end of said cas-

ing and having a chamber open to said passage and an inlet passage opening to said chamber, a valve seat at the discharge end of said inlet passage, a longitudinally fluted plug valve member slidably reciprocable in said chamber for engagement with said seat, and when seated having an opening pressure area defined by said seat and exposed to the fuel in said inlet passage, a stem reciprocable in said sleeve and having a retainer head for supporting said valve member, compression spring means between said orifice head and said retainer head for urging said valve member toward closed position, and a pintle on the outer end of said stem and coacting with said bore to define an annular restricted discharge orifice, said pintle having a peripheral undercut in communication with said down-flow passage and upon outward movement coacting with the peripheral surface of said bore to effect a progressively increasing orifice area, said valve member, said stem and said pintle constituting a differential piston having a pressure area larger than said opening pressure area and acting in opposition to said spring means to accelerate the initial opening and final closing movements of said valve member.

16. In a fuel injection nozzle, in combination, a nozzle tip having a discharge bore and a down-flow passage opening thereto, fuel inlet means opening to said nozzle tip, valve means controlling communication between said inlet means and said passage, said valve means having an opening pressure area exposed to the pressure of the fuel in said inlet means and being normally closed by spring pressure in opposition to said fuel pressure, a pintle extending reciprocably through said bore and being movable with said valve means, the outer end of said pintle having peripheral clearance with said bore to define therewith an annular restricted fuel-atomizing orifice which is of minimum flow area when said pintle is fully retracted, said pintle immediately inwardly of said outer end being formed with an axial uniformly inwardly tapered undercut open to said passage and defining an elongated spray control cone movable progressively across the outlet edge of said bore as said pintle is projected outwardly so as to effect a uniformly graduated increase of the radial orifice flow area, said pintle having an effective differential transverse area larger than said opening pressure area during the initial opening and final closing increments of movement of said valve means and adapted to be acted upon by the pressure of the fuel from said inlet means when said valve means is open.

17. A nozzle tip having a cylindrical discharge bore opening to the outer end and having a down-flow passage opening to said bore inwardly of the outer end, fuel inlet means opening to said nozzle tip, valve means controlling communication between said inlet means and said passage, said valve means including an annular seat and a ball valve member engageable with said seat and when in such engagement having an opening pressure area exposed to the pressure of the fuel in said inlet means, spring means tending to close said valve means in opposition to said fuel pressure, a pintle extending reciprocably through said bore and being movable with said valve member, the outer end of said pintle being formed with an inwardly tapered conical end defining a uniformly inwardly tapered undercut constantly open to said passage, said outer end of said pintle being movable from a position

within said bore progressively out of said bore in the opening movement of said valve means and coacting with the outer end of said bore to define an annular restricted fuel atomizing orifice of minimum radial flow area when said pintle is fully retracted, said pintle having an effective differential transverse area larger than said opening pressure area during the initial opening and final closing increments of movement of said valve means and adapted to be acted upon by the pressure of the fuel from said inlet means when said valve means is open.

18. In a fuel injection nozzle, in combination, a casing having a fuel inlet passage, and a discharge passage for discharging fuel therefrom, an outwardly opening spring-seated valve controlling communication of said inlet passage with said discharge passage and having a seat defining a valve opening pressure area, and an outwardly opening pintle movable with said valve and having an inwardly tapered symmetrical control cone at the outer end coacting during fuel discharge with said discharge passage to define a restricted annular fuel discharge orifice in uninterrupted communication with said valve, said pintle having an effective differential pressure area larger than said first mentioned area and exposed to the pressure in said casing and acting in a direction to facilitate lifting of said valve during fuel discharge, the outer end of said pintle having a narrow cylindrical land area on the periphery and being no larger in diameter than said discharge passage.

19. In a fuel injection nozzle, in combination, a casing having a chamber, a fuel inlet passage opening to said chamber, and an outlet passage in uninterrupted communication with said chamber, an outwardly opening spring-seated valve controlling said inlet passage and having a seat defining a valve opening pressure area, and an outwardly opening pintle movable with said valve and having an inwardly tapered control cone coacting with said discharge passage during fuel discharge to define a restricted fuel discharge orifice increasing progressively in uniformly graduated flow area as said valve moves toward open position, said pintle having a net effective differential pressure area larger than said first mentioned area and exposed to the pressure in said chamber and acting in a direction to facilitate lifting of said valve during fuel discharge, the outer end face of said control cone being exposed directly to the exterior of said nozzle and being no larger in area than the transverse area of said discharge passage in the plane of said orifice.

20. A fuel injection nozzle comprising, in combination, a casing having an inlet passage and an outlet cylindrical passage for discharging fuel therefrom, valve means for controlling communication between said passages and having a seat opening inwardly to said inlet passage and defining an opening pressure area, an outwardly opening valve member for coacting with said seat, and a coil compression spring tending to move said valve member toward and into engagement with said seat, a pintle outwardly of and movable longitudinally as a unit with said valve member and having an inwardly axially tapering outer end portion reciprocable in said outlet passage and coacting therewith during fuel discharge to define an annular restricted fuel-atomizing discharge orifice symmetrical about the periphery and increasing progressively in effect radial flow area upon outward move-

ment of said pintle, the outer end face of said pintle being substantially in the transverse plane of the outer end of said outlet passage when said valve means is closed, said pintle constituting a differential piston having an effective piston area larger than said opening pressure area adapted to be exposed to the fuel pressure in said casing inwardly of said orifice in the initial opening movement of said valve means and acting in opposition to said coil compression spring to effect opening and closing of said valve means with a popping action, and stop means for positively limiting the maximum extent of outward movement of said pintle.

21. A fuel injection nozzle comprising, in combination, a casing having an inlet passage and an outlet cylindrical passage for discharging fuel therefrom, valve means for controlling communication between said passages and having a seat opening inwardly to said inlet passage and defining an opening pressure area, an outwardly opening valve member for coacting with said seat, and a coil compression spring tending to move said valve member toward and into engagement with said seat, a pintle outwardly of and movable longitudinally as a unit with said

5 valve member and having an inwardly axially tapering outer end portion reciprocable in said outlet passage and coacting therewith during fuel discharge to define an annular restricted fuel-atomizing discharge orifice symmetrical about the periphery and increasing progressively in effective radial flow area upon outward movement of said pintle, the outer end face of said pintle being substantially in the transverse plane of the outer end of said outlet passage when said valve means is closed, said pintle constituting a differential piston having an effective piston area larger than said opening pressure area adapted to be exposed to the fuel pressure in said casing inwardly of said orifice in the initial opening movement of said valve means and acting in opposition to said coil compression spring to effect opening and closing of said valve means with a popping action, the outer end of said pintle having a narrow cylindrical land area on the periphery and being no larger in diameter than the outer end of said outlet passage, and means effective to limit positively the maximum height of rise of said valve member and pintle in the opening movement thereof.

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