

June 20, 1944.

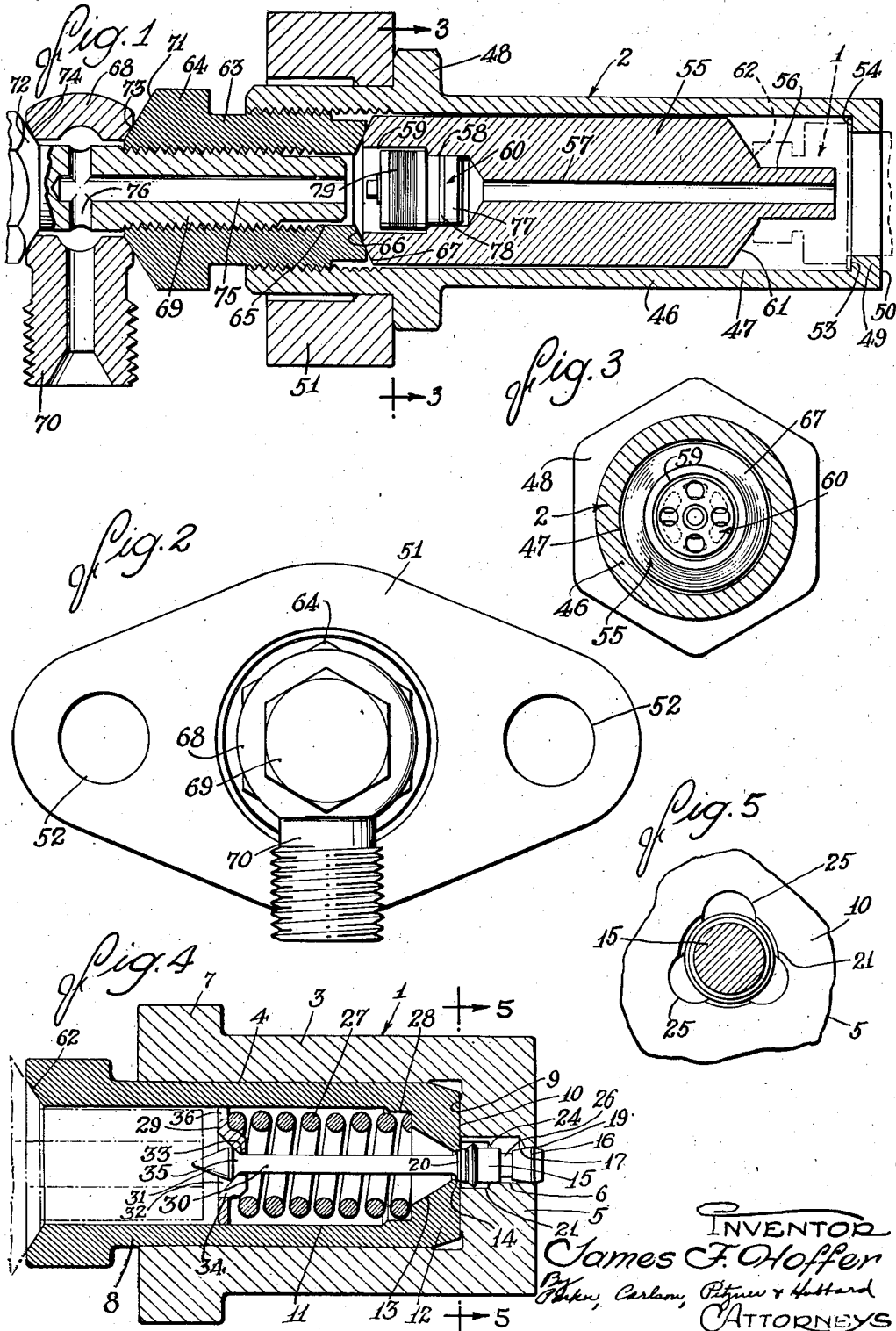
J. F. HOFFER

2,351,965

NOZZLE

Filed March 1, 1939

2 Sheets-Sheet 1



June 20, 1944.

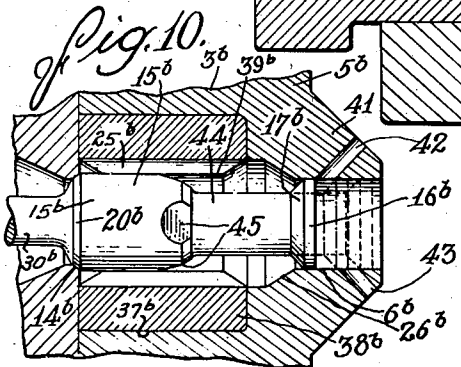
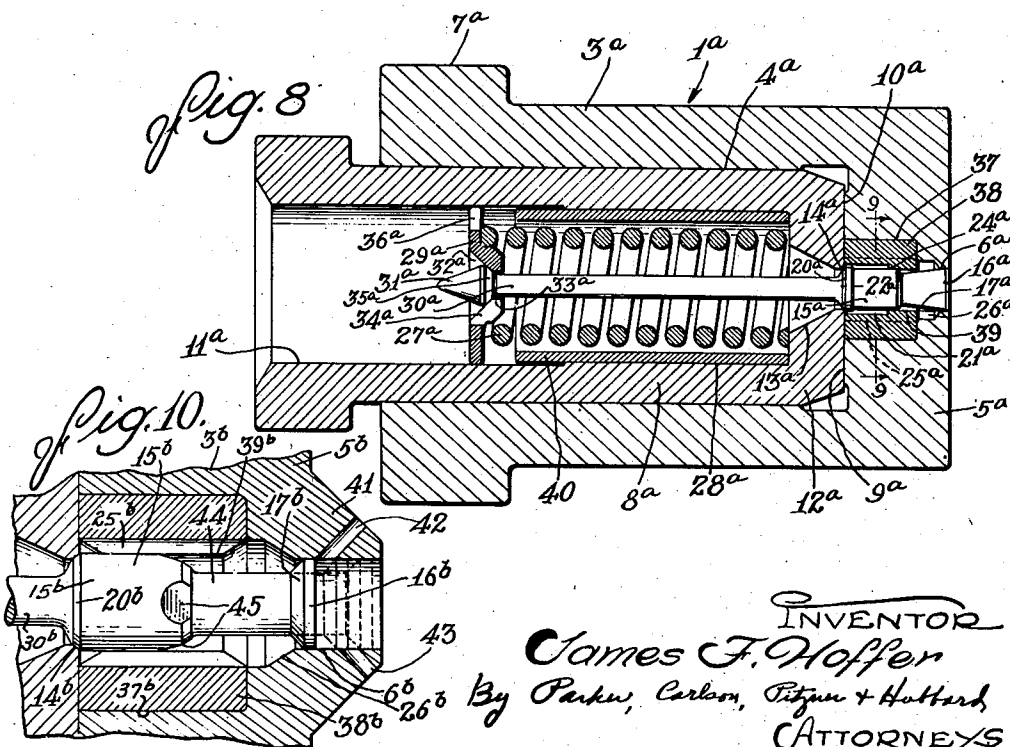
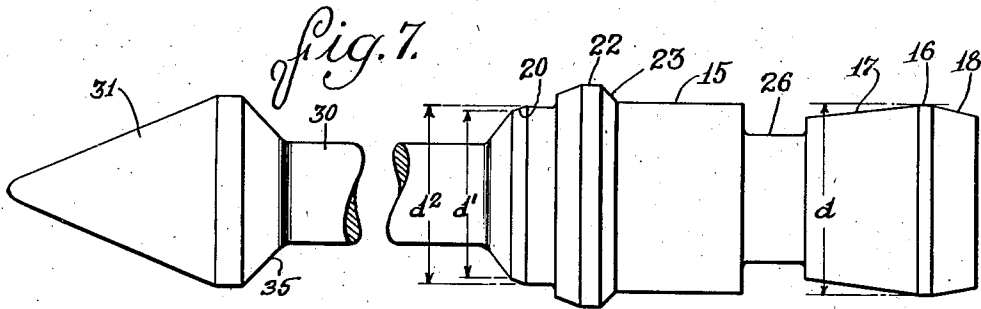
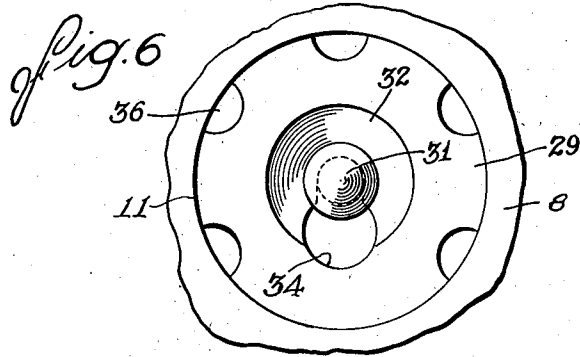
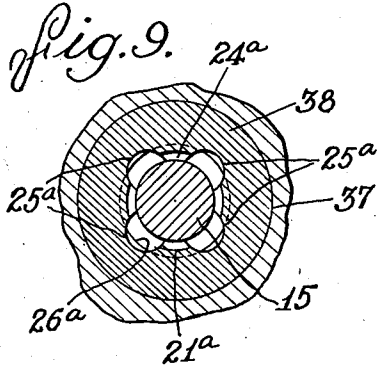
J. F. HOFFER

2,351,965

NOZZLE

Filed March 1, 1939

2 Sheets-Sheet 2



INVENTOR
James F. Hoffer
By Parker, Carlson, Pitman & Hottel
ATTORNEYS

UNITED STATES PATENT OFFICE

2,351,965

NOZZLE

James F. Hoffer, Detroit, Mich., assignor to Ex-Cell-O Corporation, Detroit, Mich., a corporation of Michigan

Application March 1, 1939, Serial No. 259,088

25 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 sharply, thereby preventing dribbling, dripping or bleeding of the fuel, and erosion on the valve seat.

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 so graduated in form as to provide in the opening movement a progressive increase in the flow area of the orifice, to control the dispersion of the spray.

A further object of the invention is to provide a novel fuel injection nozzle having a spring-seated inlet valve with a seat defining an initially effective fuel lifting pressure area when closed, and having a discharge means including a pintle movable with the valve and defining a supplemental fuel lifting pressure area of a size not setting up a negative or valve closing pressure differential and preferably being larger than said first mentioned area to create a valve opening pressure differential effective to accelerate the initial valve opening movement at least through the range of flow restriction at the seat.

Another object is to provide a new and improved fuel injection nozzle having an outwardly opening pintle in which all external leakage is avoided, and which therefore can be simple and inexpensive in construction, and is economical and efficient in operation.

Still a further object is to provide a novel fuel injection nozzle having an outwardly opening pintle which will operate efficiently over the entire speed and load range of the engine without causing smoking and detonation, and more particularly in which the volume of the fuel passage between the valve seat and the discharge orifice is but a small percentage of the volume of fuel injection at full load.

Another object is to provide a new and improved fuel injection nozzle having a lapped spherical valve seat which can be produced to correct form and with perfect surface finish without hand operation and hence at low cost, and which therefore has a long life and can be reconditioned repeatedly.

A further object is to provide a novel fuel injection nozzle in which all of the moving or working parts are housed in the nozzle tip assembly,

and are adjusted for the desired injection pressure before assembly of the tip with the holder.

Various general objects reside in providing a new and improved fuel injection nozzle which has a relatively compact and small nozzle tip, in which the weight of the moving parts is very light so as to obtain a low inertia at high speeds and reduced impact stresses, and in which the range of injection characteristics is materially increased.

A further object is to provide a novel fuel injection nozzle in which the valve stem displacement is materially reduced, thereby reducing the fuel flow through the supply tubing and pressure waves or impulses in the tubing, eliminating the use of retracting check valves or where such valves are used reducing the amount of retraction, and in general improving the speed-delivery characteristics of the injection system.

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

In the accompanying drawings,

Figure 1 is a longitudinal fragmentary sectional view of one form of a nozzle embodying features of the present invention.

Fig. 2 is a left end view of the nozzle.

Fig. 3 is a transverse sectional view of the nozzle taken along line 3—3 of Fig. 1.

Fig. 4 is an axial sectional view on an enlarged scale of the discharge tip of the nozzle.

Fig. 5 is an enlarged transverse sectional view taken along line 5—5 of Fig. 4.

Fig. 6 is an enlarged left end view of the nozzle discharge tip shown in Fig. 4.

Fig. 7 is a fragmentary side elevational view on an enlarged scale of the nozzle pintle.

Fig. 8 is a fragmentary axial sectional view of a modified form of nozzle discharge tip.

Fig. 9 is a sectional view taken along line 9—9 of Fig. 8.

Fig. 10 is a fragmentary longitudinal sectional view of still another form of discharge means.

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 fea-

tures 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 (Fig. 4) has a suitable body or housing 3. Preferably, the body 3 is in the form of a tubular shell defining an inner chamber or bore 4 and closed at the discharge end with an end wall 5 having a small bore 6 coaxial with the bore 4. An external peripheral mounting flange 7 is formed on the base end of the body 3.

Closely fitted within the bore 4 is a valve seat member 8 having an inner end face or surface 9 in pressure tight engagement with the inner face or surface 10 of the end wall 5 about the bore 6. The valve seat member 8 is tubular in form to provide an axial passage or bore 11, and projects from the open end of the tip body 3 for fluid tight connection to the source of fuel supply. The inner end of the seat member 8 has an end wall 12 formed with a central opening or bore 13 terminating in an annular valve seat 14. This opening consists of a short cylindrical portion defining the minor diameter of the seat 14 and a flared portion opening therefrom to the bore 11.

A pintle 15 extends slidably through the discharge bore 6 and coacts therewith to define a discharge orifice means having the desired fuel discharge characteristics for proper atomization and penetration. By selective variation in the form of the bore or passage 6 or the pintle 15 or both, different spray patterns and characteristics may be obtained as desired to best suit different engine requirements. In the present instance, the discharge end of the bore 6 is of constant diameter, and the pintle 15 consists of a cylindrical stem which is formed adjacent its outer end portion with a spray control form consisting of a narrow cylindrical area 16 of full pintle diameter d , an inner control cone 17 defined by a peripheral groove or undercut and tapered inwardly from the area 16; and an outer cone or conical surface 18 tapered outwardly from the area 16 to the end of the pintle. The pintle 15 coacts with the bore 6 to define a single annular discharge orifice 19, and is movable outwardly in the opening movement of the nozzle to obtain a progressively increasing orifice area.

When the nozzle is closed, the pintle 15 occupies a position, as shown in Fig. 4, in which the inner edge of the control area 16 is located a short distance, for example, about five per centum of the full valve lift, inside the outer end of the bore 6, and the outer cone 18 projects a short distance from the bore. The control area 16, which is less in diameter than the bore 6, defines the minimum orifice area, and the outer cone 18 causes the cylindrical fuel spray to converge so as to obtain increased penetration in instances where this is desirable. It will be evident that the minimum orifice area is maintained during the initial opening movement of the nozzle, i. e., until the inner edge of the area 16 passes from the bore 6, and that thereafter, in the continued opening movement, the orifice area is automatically increased at a rate as determined by the form of the inner cone 17.

Small fuel charges require a correspondingly small orifice area. The minimum orifice area is

of such size that the minimum quantities of fuel that may be required per injection will be introduced into the combustion chamber entirely in proper form for combustion so as to obtain satisfactory power, good idling operation, efficient fuel consumption, and smokeless and quiet combustion. This requires that the minimum orifice area be made small enough to cause the pressure to build up at the orifice inlet sufficiently to obtain adequate fuel injection velocity.

Formed on the inner end of the pintle 15 is an annular valve face or seat 20 adapted for engagement with the stationary seat 14. Also formed on the pintle 15 adjacent the seat 20 and movable in a counterbore or chamber 21 in the inner end of the bore 6 is a peripheral rib 22. The rib 22 defines a conical abutment shoulder 23 adapted for engagement with a fixed conical stop shoulder 24 at the end of the counterbore 21 to limit the opening movement of the pintle 15.

A free path of fuel flow from the valve 14, 20 to the orifice 19 is afforded by a plurality of spaced longitudinal passages 25. Preferably, these passages are provided by partial bores which longitudinally intersect the surfaces of the bore 6 and counterbore 21, and which extend from the inner face 10 of the wall 5 to the region of the inner control cone 17. Formed in the pintle 15 at the inner end of the conical undercut 17 is an annular groove 26 which serves to effect equalization of the pressure and velocity of the fuel issuing from the passages 25 about the taper so that the discharge fuel spray is essentially uniformly distributed and of circular form.

It is important that the valve seats 14 and 20 hold tightly to prevent the passage of fuel until the full valve opening pressure (VOP) is attained. In the present instance, the valve seats 14 and 20 are spherical in shape, and hence can be machine lapped. Since the valve seat member 8 is removable from the tip body 1, the seats 14 and 20 can be oscillated in an orbital movement while in engagement so as to lap the mating valve surfaces to the desired spherical shape. The flared portion of the opening 13 provides clearance in the seat member 8 to permit this combined rotary and oscillatory movement during the lapping operation. The spherically lapped valve seats are accurately mated and have a perfect surface finish. As a result, they have a long life and are effective to prevent valve leakage up to the valve opening pressure. Also, manufacturing costs are reduced because of the avoidance of hand operations and the usually attendant scrapping of imperfectly formed parts. Since their boundaries overlap, the seats can be reconditioned repeatedly without the formation of ridges or shoulders as would result in attempting to recondition conical seats.

A coil compression spring 27 serves to close the valve 14, 20 with a predetermined spring pressure, and as an incident thereto to retract the pintle 15 into its innermost position. The spring 27 is mounted within the seat member 8, and at one end impinges against the inner surface of the wall 12 about the opening 13, and is centered by the end of the bore 11 which is reduced in diameter as indicated at 28. At the other end, the spring 27 impinges against a hanger 29 slidably disposed in the bore 11 and suitably anchored to the pintle 15. In the preferred form, the pintle 15 is provided with an elongated axial shank or neck 30 having an enlarged head 31 at its free inner end. The hanger 29 consists of a circular disk having

an axially offset portion which serves to center the adjacent end of the spring 27, and which defines an outwardly opening socket 32 having a central opening 33 to receive the shank 30. The opening 33 is larger than the shank 30 to provide clearance permitting limited angular adjustment of the hanger 29 to the end plane of the spring 27. A clearance hole 34 of sufficient size to receive the head 31 intersects one side of the opening 33 to permit assembly of the hanger 29 and the shank 30. When the parts are assembled as shown, the socket 32 is in pilot engagement with an abutment shoulder 35 on the base of the head 31. This shoulder, although conical in form, is in effect spherical in action to permit relative rotation of the engaging parts about a point in the center of the guide plane of the disk 29, so as to prevent eccentricity because of angulation and to avoid side pressure on the pintle 15 and hanger 29. A plurality of peripherally spaced notches 36 are formed in the hanger disk 29, and supplement the opening 33 to provide an adequate area for unrestricted fuel flow past the hanger.

To cause the valve 14, 20 to open sharply, i. e., with an increased acceleration or popping action, the effective area of the pintle 15, which in the position immediately following the initial seat opening is determined by the diameter d of the land 16, is made at least as large as the valve opening area to prevent a negative differential, and preferably is made larger to provide a valve opening differential. The valve opening pressure area is mainly determined by the diameter of the seat 14. In practice, the effective diameter of the valve opening area exposed to the lifting pressure of the incoming fuel may be somewhat greater than the inner or minor diameter d' of the seat 14 and somewhat less than the outside or major diameter d^2 of the seat, the exact diameter being partially influenced by such factors as surface finish, fuel viscosity, static seat stress and the rate of fuel supply.

The volume of the fuel space between the valve seat 14 and the orifice 19 is a consideration in the proper performance of the nozzle. This space consists mainly of the space between the pintle 15 and the surface of the counterbore 21, the passages 25 and the space defined by the undercut 17 and the groove 26 in the pintle. The fuel in this space is exposed to the heat of the nozzle tip, and part thereof may therefore be gasified by residual heat during intervals between injections, and caused to escape without proper timing into the engine combustion chamber. Gasified fuel entering the combustion chamber during the exhaust stroke of the piston tends to result in engine smoking. If the gasified fuel enters the chamber at an improper time during the compression stroke, detonation may result. Consequently, if the volume of residual fuel in the space between the valve 14, 20 and the orifice 19 is too large in relation to the total volume of each charge per injection, the engine is likely to operate improperly and inefficiently.

Improper combustion is most likely to occur at idling operation. At this time, the ratio of the volume of the fuel space below the valve seat to the volume of the fuel charge is at a maximum. If the ratio is sufficiently in excess of one (1), enough of the fuel in the space may be gasified and discharged during each period between successive nozzle operations to thereupon permit each new fuel charge to merely refill the space without causing the properly timed injection of liquid fuel.

In the present invention, improper combustion is minimized or entirely avoided by limiting the volume of the fuel space below the valve seat to within a permissible maximum. The volume of the space is made as small as feasibly possible in relation to the minimum volume of fuel per injection, the ratio being confined to a range from 0 to 1. Consequently, the volume of the fuel in the space is never in excess of the volume of fuel periodically supplied, even at minimum quantity requirements, and as the rate of injection increases, the ratio becomes correspondingly less. For example, the fuel space may be approximately eight cubic millimeters for present small Diesel engines in which the idling fuel charge is approximately ten to twelve cubic millimeters, and the full load charge is approximately fifty to sixty millimeters per injection.

In providing such reduced fuel space, the flow area of the passages 25 should, however, be retained sufficiently large to prevent objectionable flow restriction. I have found that the minimum flow area of the passages 25 should be approximately four times as large as the maximum flow area of the orifice 19. For a given flow area, the volume of the fuel space is influenced by the length of the passages 25 in turn dependent on the length of the pintle 15. Therefore, the pintle 15 is provided with a length not below a minimum sufficient to satisfy inherent mechanical and hydraulic operating requirements of the nozzle, and not above a maximum short enough to satisfy the maximum permissible volume requirements of the fuel space. It will be evident that location of the spring 27 at the inlet side, instead of the outlet side, of the valve 14, 20, facilitates the provision of the desired length of pintle and the correct proportioning of related parts.

The diametrical size of the pintle 15 may be varied within a certain range depending on the injection characteristics desired, and influences the dimensions of the other coating parts of the nozzle. A relatively small diameter is best suited for high penetration. As the diameter is reduced, more clearance between the pintle 15 and the bore 6 is permissible for a given minimum orifice flow area, and hence the thickness of the fuel sheet is increased. Also, the annular spray has a shorter radial distance to converge after issuing from the nozzle, and the volume of the fuel space below the valve seat 14 is reduced. Conversely, as the pintle diameter is increased, the issuing sheet of spray becomes thinner, and has a greater distance to converge so that less penetration is obtained.

The diameter of the pintle 15 is made sufficiently large to permit the use of the desired valve operating differential, and at the same time to provide adequate physical strength in the other parts of the nozzle and an adequate flow area through the valve. I have found that the useful range of pintle diameters d is from .040" to .120".

The valve operating differential is determined by the ratio of the circumscribed area of the valve seat 14, when the valve is closed, to the transverse area of the pintle 15. Taking the minor diameter d' as the effective seat diameter, the ratio may be expressed as

$$\left(\frac{d'}{2}\right)^2 \times \pi \div \left(\frac{d}{2}\right)^2 \times \pi$$

Theoretically, the area differential so expressed bears a direct relationship to the ratio of the valve closing pressure (VCP) to the valve open-

ing pressure (VOP), and hence may also be expressed as VCP/VOP. By way of illustration, if the minor seat diameter d' is taken as .06405", providing a seat area of .00322 square inch, and the pintle diameter d is taken as .070", providing an area of .00385 square inch, the theoretical differential ratio equals .836. If the fuel pressure required to open the valve against the action of the spring 27 is taken as 1550 pounds per square inch, the valve closing pressure will be 1297 pounds per square inch, and the pressure differential will be 253 pounds per square inch. In the present outwardly opening pintle nozzle, the differential pressure and ratio is influenced by the engine compression pressure. This compression tends to increase the VOP, thus assisting the spring 27 in closing the valve 14, 20 and in maintaining the valve tightly closed between injection periods. In the foregoing example, a compression pressure of 450 pounds per square inch, supplementing a five (5) pound spring 27, would increase the VOP to 2060 pounds per square inch and the differential pressure to 310 pounds per square inch.

The differential of VCP/VOP serves to effect quick opening and closing of the valve 14, 20, thereby protecting the valve seats against cavitation erosion. This is especially desirable at low speeds where the rate of discharge from the nozzle is likely to be materially influenced by factors other than the rate of fuel pump delivery. The ratio of VCP/VOP may be varied as desired for different kinds and sizes of engines, and for different injection requirements. I have found that the useful ratio of VCP/VOP falls within a range of from .5 to 1.

The shank or stem 30 extends axially through the bore 13, and coacts therewith to define an annular flow passage through the valve seat 14. This passage should have a sufficient capacity to avoid setting up objectionable flow restrictions. Therefore, the transverse area of the stem 30 is limited by the circumscribed seat area of the valve 14, 20. Since the diametrical size of the head 31 is limited to permit a sufficient amplitude of orbital rocking in the lapping of the valve seats, and also for assembly through the seat, the stem area must also be small enough to provide an adequate stress area on the shoulder 35. I have found that the transverse stem area, which is approximately twenty-five per cent. (25%) of the full pintle area, should have a ratio to the circumscribed valve seat area coming within a useful range of from .2 to .3.

Another factor influencing the operation of the nozzle is the weight of the moving parts. It is desirable that this weight be as low as possible in relation to the maximum quantity of fuel per injection so as to avoid or minimize mechanical nozzle noise at light loads, to reduce impact noise and to reduce stress on the parts. In the present outwardly opening pintle nozzle, the weight of the moving parts is very low. This is made possible because of the fact that the valve seat 14, 20 is no larger and may be made smaller in area than the pintle 15, and because the weight of the other parts may be proportionately low. I have found it desirable that the ratio of the weight of the moving parts affecting inertia to the weight of the maximum quantity of fuel per injection come within a range of from 1 to 25. The exact ratio is determined by dividing the weight of moving parts affecting inertia by the weight of the maximum quantity of fuel per injection.

The height of rise of the pintle 15, i. e., the maximum stem displacement, also has desirable limits. As the height of rise is increased, the angle of the control cone 17 can be advantageously reduced to obtain an injection spray of greater penetration for a pintle of a given diameter. However, the pintle 15 will tend to act objectionably as a pump plunger if the height of rise is too great. It is therefore desirable that the ratio of the volume of maximum stem displacement to the maximum volume of fuel per injection come within the range of from 0 to .1. The exact ratio is determined by dividing the volume displaced for maximum pintle movement by the maximum volume of fuel per injection.

In operation, fuel under pressure, entering the bore 11 from the pump or other suitable source, passes through the openings 34 and 36 in the hanger 29, and acts on the valve opening area of the seat 20. The fuel pressure increases rapidly, and, when it exerts a force sufficient to overcome the opposing pressure of the spring 27, causes the valve 14, 20 to open. As the valve starts to open, a small amount of fuel passes there-through to the fuel space leading to the orifice 19, and builds up an opening pressure, by reason of the orifice restriction, immediately effective on the full transverse area of the pintle 15 which is larger than the initial valve opening area. This increase in pressure area causes the valve 14, 20 to open sharply, i. e., with an accelerated or popping action, and to move quickly into a position of equilibrium in which the hydraulic force balances the pressure of the spring 27 or into full open position determined by engagement of the shoulders 23 and 24.

When the valve 14, 20 is in closed position, it has a sufficiently tight seat engagement by reason of the surface finish to prevent seepage or leakage until the maximum valve opening pressure is attained. During the initial opening movement of the valve, the minimum orifice opening is small due to the close fit of the pintle 15 in the bore 6, and remains constant until the land 16 is moved out of the bore. The opening is sufficiently small to prevent excessive leakage or injection of the fuel from the orifice 19 until the flow area through the valve 14, 20 is adequate in relation to the orifice area to prevent flow restriction at the valve. The mechanical friction of the moving parts is so low that a very slight pressure increase on the effective transverse pintle area will result in an additional pintle movement. By reason of the foregoing conditions, the valve opening movement is extremely rapid, thereby resulting in a desired high velocity of flow through the orifice 19, and a velocity of flow through the valve particularly at initial opening and final closing sufficiently low to avoid valve seat erosion. It will be understood that the extent of valve opening is determined by the ultimate pressure of the fuel. For small injections, the pintle 15 in some instances may not be displaced sufficiently to move the land 16 out of the bore 6, and in this event, the minimum orifice area is the idling orifice area. As the fuel pressure is increased, the hydraulic force will be increased to effect a greater spring compression and consequently a greater pintle movement within the mechanically defined limits. In the case of large injections at relatively high pump speeds, the hydraulic pressure may increase more rapidly than the spring pressure, and therefore, cause the pintle 15 to engage the height of rise

stop shoulder 24 which limits the valve opening movement.

The fuel is discharged from the orifice 19 in the form of an annular spray. As the pintle 15 is moved outwardly, the control cone 17 causes the flow area of the orifice 19 to increase progressively.

At or near the end of the injection period, as determined by the cessation of fuel supply, the hydraulic pressure on the full transverse area of the pintle 15 starts to drop to permit the spring 27 to return the valve 14, 20 progressively toward closed position. This continues until the flow area through the valve is reduced to a point where the hydraulic pressure at the outlet side of the valve starts to drop relatively to the inlet fuel pressure. Thereafter, an unstable condition exists between the oppositely acting hydraulic pressure and spring pressure, and this condition tends to close the valve with great rapidity. The final valve closing pressure is lower than the initial valve opening pressure as determined by the difference in the valve opening area of the seat 20 and the full transverse area of the pintle 15. When the valve is fully closed, it shuts off the supply of fuel to the orifice 19 and prevents any possible return flow of gases from the combustion space.

A modified form of nozzle tip 1^a, generally similar to the tip 1 but differing therefrom in certain specific respects hereinafter described, is illustrated in Fig. 8. The tip 1^a has a tubular body 3^a which is formed with an axial bore 4^a closed at one end by a wall 5^a, and which is provided at the other end with a peripheral mounting flange 7^a. Opening through the wall 5^a coaxially with the bore 4^a is a discharge bore 6^a having an intermediate counterbore defining a fuel distribution chamber 26^a and having a larger inner counterbore 37. A tubular sleeve or bushing 38 is tightly fitted into the counterbore 37, and is formed with a bore 39 coaxial with and of the same diameter as the bore 6^a. The inner end of the bore 39 is counterbored to define a valve chamber 21^a opening flush with the inner surface or face 10^a of the wall 5^a and to provide a narrow emergency stop shoulder 24^a. A plurality of peripherally spaced internal longitudinal flow passages 25^a are broached in the sleeve 38 and serve to connect the valve chamber 21^a to the distribution chamber 26^a.

Closely fitted into the bore 4^a is a tubular valve seat member 8^a having an end wall 12^a with an outer surface or face 9^a in engagement with the face 10^a, and having an axial bore 23^a opening to the wall 12^a and formed with a counterbore 11^a open to the other end. A tubular stop sleeve 40 is fitted within the bore 23^a against the wall 12^a, and projects a short distance into the counterbore 11^a. Opening from the sleeve 40 through the end wall 12^a to the valve chamber 21^a is a valve inlet passage or opening 13^a terminating in an annular fixed valve seat 14^a of spherical form.

A pintle 15^a is reciprocable in the aligned bores 6^a and 39, and is formed on its outer end with a narrow peripheral land 16^a and a contiguous inner spray control cone 17^a tapering inwardly therefrom through the distribution chamber 26^a. The inner end of the pintle 15^a is formed with an annular movable valve seat 20^a of spherical form adapted for engagement with the seat 14^a, and with a peripheral rib 22^a adapted for engagement with the shoulder 24^a to limit the outward movement of the pintle. As in the form of Fig. 1, the

valve opening pressure area, which is defined by the area circumscribed by the movable valve seat 20^a and exposed to the passage 13^a when the valve is closed, is smaller than the full transverse pintle area at the land 16^a.

The pintle 15^a has an axial shank or neck 30^a of reduced diameter extending inwardly through the valve passage 13^a and the sleeve 40, and provided at its free end with an enlarged head 31^a presenting a conical abutment shoulder 35^a facing the valve. A circular disk hanger 29^a is slidable in the counterbore 11^a, and is formed with an axially offset socket 32^a engaging the abutment shoulder 35^a. The hanger 29^a has a central opening 33^a in the socket 32^a receiving the pintle shank 30^a, and an eccentric clearance hole 34^a intersecting one side of the opening 33^a and of sufficient size to receive the head 31^a for assembly purposes. A coil compression spring 27^a of predetermined pressure encircles the shank 30^a within the sleeve 40, and abuts at one end against the wall 12^a and at the other end against the hanger 29^a where it is centered by the exterior of the wall of the socket 32^a. The hanger 29^a also is formed with notches 36^a which with the hole 34^a provide a flow area permitting unrestricted fuel flow to the valve.

In this form of the invention, the height of rise of the valve in normal operation is limited by engagement of the hanger 29^a with the adjacent end of the stop sleeve 40. The shoulder 24^a merely constitutes a safety stop to prevent the pintle head from entering the combustion chamber in the event that the shank 30^a should break. In nozzles employing a high rate spring and providing a comparatively large height of valve rise, the normal height of rise stop may be eliminated since the spring pressure will balance the hydraulic pressure at a height of rise within the defined mechanical limits of valve movement.

The modified form of nozzle tip permits the volume of the fuel space between the valve and the discharge orifice 19^a to be materially reduced. This reduction in volume is especially advantageous in reducing smoke at idling operation on the smallest Diesel engines now in use. The reduced volume is partly attributable to location of the height of valve rise stop remote from the pintle 15^a at the inlet side of the valve, thereby reducing the volume of the chamber 21^a since the rib 22^a and the shoulder 24^a are comparatively small. The four broached down-take passages 25^a which open to the intermediate counterbore 26^a have no effect on the spray form so that an improved penetration and shape of spray is obtained. In general, a greater height of valve rise is permitted, and therefore the spray control cone 17^a is materially reduced in angularity. As a result, the fuel spray is more concentrated and penetrating which is very desirable for certain types of combustion chambers.

A third form of the invention, in which the pintle is adapted for valving multiple hole orifices, is illustrated in Fig. 10. It is generally similar to the form of Fig. 8, and hence corresponding parts are identified by the same reference numerals plus the letter b, and only the differences are specifically described.

The end wall 5^b of the body 3^b is formed with an axial conical projection 41 through which the bore 6^b extends. A plurality of diverging hole orifices open from the bore 6^b through the projection 41. These orifices may be provided in any desired number, and may be of any suitable form and arrangement for valving in any desired or-

der. In the present instance, two orifices 42 and 43 are shown. They are in the form of straight bores of the same diameter, spaced diametrically opposite each other, and inclined to extend perpendicularly to the conical surface of the projection 41.

The pintle 15^b is formed on the outer end with a narrow peripheral land 16^b slidable in the bore 6^b to valve the orifices 42 and 43 and a contiguous short inner spray control cone 17^b of high angle for directing the fuel from the chamber 26^b into the orifices. Preferably, the angle of the cone 17^b is the same as that of the orifices 42 and 43 so as to avoid impingement of the fuel on the surfaces of the latter. The velocity of the fuel is thereby maintained and caused to break up the spray against the air into which the fuel is injected.

The orifices 42 and 43 are located outwardly of the pintle 15^b when the valve 14^b, 20^b is closed, as indicated in full outline. One orifice, 42, is arranged to be opened immediately after movement of the pintle 15^b through the width of the land 16^b, and the other orifice, 43, is arranged to be opened immediately after the first orifice is fully open. Hence, the opening of the orifices 42 and 43 occurs in close sequence, although it is to be understood that the orifices can be so arranged that opening thereof will overlap or occur simultaneously.

The inner end portion of the pintle 15^b is separated from the control cone 17^b by a cylindrical section 44 of a smaller diameter, and is guided in the bore 39^b which is of constant diameter substantially through the sleeve 38^b. Opposite ends of the bore 39^b are chamfered, and the outer end of the guide portion of the pintle 15^b is also chamfered and formed with inclined flats 45, to afford unrestricted ingress and egress of the fuel to and from the down-flow grooves 25^b.

In the initial opening movement of the valve 14^b, 20^b, the land 16^b starts to move across the inner end of the orifice 42. As soon as the inner edge of the land 16^b reaches the orifice 42, the latter starts to open. Thereafter, the pintle 15^b continues to open the orifice 42 progressively. When the pintle 15^b has fully uncovered the orifice 42, as indicated in the first dotted position, it starts to open the orifice 43. The pintle 15^b continues to open the orifice 43 progressively, and when it has fully uncovered the latter, as indicated in the second dotted position, the nozzle is fully open.

The holder 2 is adapted to support any one of the nozzle tips 1, 1^a and 1^b in operative position to inject fuel into a combustion chamber (not shown), and to connect the tip to a fuel supply line leading from a suitable fuel source. Considering the nozzle tip 1, and referring to Figs. 1 to 4, the holder 2 comprises an outer body or housing 46. Preferably, the holder body 46 consists of an elongated generally tubular shell having a longitudinal bore 47 and an external peripheral hexagonal mounting flange 48. One end of the body 46 is formed with an inner peripheral flange 49 for holding the nozzle tip 1, and has an end surface 50 adapted to be clamped through a gasket (not shown) against a mating surface (not shown) in the engine cylinder head (not shown) to provide a gas-tight seal. A clamp plate 51 closely encircles the outer end of the body 46, and engages the outer face of the mounting flange 48. The plate 51 is formed at opposite sides of the body 46 with suitable holes 52

through which bolts (not shown) may be inserted to clamp the holder 2 in position.

The mounting flange 7 of the nozzle tip 1 is positioned against the inner surface 53 of the flange 49, a suitable gasket 54 being interposed therebetween, and the tip projects through the flange 49 to extend into the combustion chamber of the engine. Removably inserted into the holder body 46 is a cylindrical filter holder 55 having an axial stem 56 on one end extending into the inner end of the bore 11 of the valve seat member 8, and having an axial bore or passage 57 opening therethrough. The inlet end of the bore 57 is formed with two counterbores 58 and 59 in which a fuel filter 60 is removably mounted. The filter holder 55 is formed on one end, at the base of the stem 56, with a conical abutment surface 61 adapted for fluid-tight engagement with an annular mating surface 62 on the inner end of the valve seat 8 coaxial with the bore 11. A nut 63, with an outer hexagonal head 64 and an axial bore 65 opening therethrough, is threaded into the outer end of the bore 47 of the holder body 46, and is formed on the inner end with a coaxial conical abutment surface 66 in fluid-tight engagement with a mating surface 67 on the filter holder 55. It will be seen that when the nut 63 is tightened, it will clamp the nozzle tip 1 and the filter holder 55 securely in position within the holder 2 while maintaining sealed communication between the aligned bores 11, 57 and 65.

High pressure tubing from a fuel injection pump or other fuel source (not shown) may be suitably connected to the outer end of the nut 63. In the present instance, a hollow fitting 68 is removably clamped with a pressure-tight seal against the outer end of the nut 63 by a bolt 69 threaded into the outer end of the bore 65. The fitting 68 loosely encircles the shank of the bolt 69, and has a laterally extending threaded nipple 70 adapted to be connected to the tubing. The outer end of the nut 63 and the head of the bolt 69 are formed with opposed coaxial conical abutment surfaces 71 and 72 adapted for pressure-tight engagement with mating surfaces 73 and 74 in opposite sides of the fitting 68. It will be seen that when the bolt 69 is tightened, the fitting 68 will be tightly clamped in position. The bolt 69 is formed with an axial bore 75 which opens to the counterbore 59, and which is connected through a plurality of intersecting radial ports 76 in the shank of the bolt to the interior of the fitting 68.

The filter 60 may be of any suitable character, and preferably is of the disk type. In the form shown, the filter 60 comprises a cylindrical body 77 with a seal ring 78 fitted tightly within the counterbore 58. A plurality of filtering disks 79 are clamped in coaxial relation to the body 77 within and in peripherally spaced relation to the counterbore 59.

In operation, fuel supplied from the source passes through the fitting 68, the ports 76, the bore 75, the filter 60 and the bore 57 to the nozzle tip 1. The holder 2 permits the filter 60 to be installed without removing the nozzle tip 1 from the engine. Being mounted directly in the nozzle holder 2, the filter 60 is located close to the tip 1, and requires no threaded connections.

The holder, with the filter, is disclosed and claimed in my copending divisional application Serial No. 534,440, filed May 6, 1944.

I claim as my invention:

1. In a fuel injection nozzle, in combination, a casing having a fuel inlet valve passage and a discharge passage opening from said casing, an outwardly opening valve controlling said inlet passage and having an annular seat defining a valve opening pressure area, a valve member and a coil compression spring tending to engage said member with said seat, the opening through said seat constituting the sole path of fuel inlet to said discharge passage, and an outwardly opening pintle movable with said valve member 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 integral shank extending in peripherally spaced relation through said seat and having an effective pressure area larger than said first mentioned area and exposed to the pressure in said discharge passage and acting during fuel discharge in a direction to lift said valve, 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.

2. In a fuel injection nozzle, in combination, a casing having a fuel inlet valve passage, and a discharge passage opening from said casing, an outwardly opening valve controlling said inlet passage and having a seat defining a valve opening pressure area, a valve member and a coil compression spring tending to engage said member with said seat, said passages being in uninterrupted communication when said valve is open during fuel discharge and the opening through said seat constituting the sole path of fuel inlet to said discharge passage, and an outwardly opening pintle movable with said valve member 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 an integral shank extending in peripherally spaced relation through said seat and having a net effective pressure area larger than said first mentioned area and exposed to the pressure in said discharge passage and acting during fuel discharge in a direction to lift said valve, 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.

3. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge bore, an outwardly facing annular valve seat formed in said passage in axial alignment with said bore, a pintle reciprocable in said bore and coacting with the outer edge of said bore during fuel discharge to define an annular discharge orifice, an outwardly opening valve seat integral with said pintle and coacting with said first mentioned seat to define an outwardly opening valve controlling said passage, an axial shank on said pintle and extending through said first mentioned seat, a valve hanger connected to said shank and slidably guided in said inlet passage and a spring acting on said hanger at the inlet side of said valve in a direction to close said valve, the outer end of said pintle being formed with a narrow peripheral land for defining with the

outer end of said bore the minimum orifice area during the initial opening movement of said valve, and a contiguous control cone uniformly tapering inwardly from said land for defining with said outer end of said bore a progressively increasing orifice area in the continued opening movement of said valve.

4. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge bore, an outwardly facing annular spherical concave fixed valve seat formed in said passage in axial alignment with said bore, a pintle reciprocable in said bore and coacting with said bore to define a controlled discharge orifice, an outwardly opening spherical convex movable valve seat integral with said pintle and complementary in shape to and coacting with said fixed seat to define an outwardly opening valve controlling said passage, an axial shank on said pintle and extending through said fixed seat and inwardly from said fixed seat in peripherally spaced relation throughout its length from the wall of said inlet passage with clearance to permit in the assembling of said nozzle lateral oscillation of said shank in any direction while said seats are in engagement, a guide member removably engaged with the inner end of said shank for centering said shank during normal operation, and a spring acting on said shank at the inlet side of said valve in a direction to close said valve.

5. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge bore, an outwardly facing annular fixed valve seat formed in said passage in axial alignment with said bore, a pintle reciprocable in said bore and coacting during fuel injection with the outer edge of said bore to define an annular discharge orifice, an outwardly opening movable valve seat integral with said pintle and coacting with said fixed seat to define an outwardly opening valve having a valve opening pressure area exposed to said passage, said valve defining and controlling the sole path of fuel flow from said passage to said bore, an axial shank on said pintle and extending through said fixed seat, a spring hanger anchored centrally to the inner end of said shank, and a coil compression spring seated at one end in said casing and engaging at the other end against said hanger and acting through said hanger on said shank at the inlet side of said valve in a direction to close said valve, said pintle having a pressure area at the outlet side of said valve larger than said first mentioned area and acting in a direction to lift said valve during fuel discharge.

6. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge bore, an outwardly facing annular fixed valve seat formed in said passage in axial alignment with said bore, a pintle reciprocable in said bore and coacting with said bore to define a controlled discharge orifice, an outwardly opening movable valve seat integral with said pintle and coacting with said fixed seat to define an outwardly opening valve controlling said passage, the outer end of said pintle being formed with a tapered control element to provide a progressively increasing orifice area in the opening movement of said valve, and with a narrow peripheral groove at the inner end of said element of a diameter less than the minimum diameter of said element, downflow passages formed in the peripheral wall of said bore and opening from said valve along said pintle to said groove, and spring

means acting on said pintle in a direction to close said valve.

7. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge bore, an outwardly facing annular fixed valve seat formed in said passage in axial alignment with said bore, a pintle reciprocable in said bore and coacting with said bore to control the rate of discharge therefrom, an outwardly opening movable valve seat integral with said pintle and coacting with said first mentioned seat to define an outwardly opening valve controlling said passage, an axial shank on said pintle and extending through said fixed seat to define therewith an annular valve passage, and spring means acting on said shank at the inlet side of said valve in a direction to close said valve, the transverse area of said shank having a ratio to the circumscribed area of said fixed seat within a range of from .2 to .3.

8. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge bore, an outwardly facing annular fixed valve seat formed in said passage in axial alignment with said bore, a pintle reciprocable in said bore and coacting with said bore to control the rate of discharge therefrom, an outwardly opening movable valve seat integral with said pintle and coacting with said first mentioned seat to define an outwardly opening valve controlling said passage, an axial shank on said pintle and extending through said fixed seat to define therewith an annular valve passage, and spring means acting on said shank at the inlet side of said valve in a direction to close said valve, said shank in said valve passage having a transverse area which is approximately equal to one-fourth of the transverse area of said pintle and which bears a ratio to the area circumscribed by the inner circumference of said fixed seat within a range of from .2 to .3.

9. In a fuel injection nozzle, in combination, a casing having a fuel inlet passage and an outlet passage, an outwardly opening spring-seated valve controlling said inlet passage and having a seat defining a valve opening pressure area constituting the sole fuel inlet to said outlet passage, and a pintle movable with said valve and coacting with said outlet passage to define an annular fuel discharge orifice, said pintle having a pressure area at the outlet side of the valve as large as said first mentioned area and responsive during fuel injection to the pressure of the fuel when said valve is moved out of closed position and acting in a direction to lift said valve, said pintle having a valve stem extending in spaced relation through said seat, and coiled compression spring means coacting with the inner end of said stem inwardly of said seat and tending to close said valve.

10. In a fuel injection nozzle, in combination, a casing having a fuel inlet passage and an outlet passage, an outwardly opening spring-seated valve controlling said inlet passage and having a seat defining a valve opening pressure area constituting the sole fuel inlet to said outlet passage, and a pintle movable with said valve and coacting with said discharge passage to define an orifice for controlling the fuel discharge from the nozzle, said pintle having a pressure area at the outlet side of said valve and adapted to act in a direction to lift said valve in response to the fuel pressure, the ratio of said valve opening area to said last-mentioned pressure area coming within a range of from .5 to 1, said pintle when said

valve is closed being retracted at the point of maximum diameter within said outlet passage, said pintle having a valve stem extending in spaced relation through said seat, and coiled compression spring means coacting with the inner end of said stem inwardly of said seat and tending to close said valve.

11. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge bore, an outwardly facing annular valve seat formed in said passage in axial alignment with said bore, a pintle reciprocable in said bore and coacting with the outer edge of said bore to define an annular discharge orifice, an outwardly opening valve seat integral with said pintle and coacting with said first mentioned seat to define an outwardly opening valve controlling said passage, downflow passage means opening from said valve to said orifice, and spring means acting on said pintle in a direction to close said valve, the ratio of the volume of the fuel space between said valve and said orifice to the volume of the minimum quantity of fuel per injection coming within a range of from 0 to 1.

12. 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, a pintle movable with said valve and coacting with said discharge passage to define a restricted fuel discharge orifice, said pintle having a pressure area larger than said first mentioned area and exposed to the fuel pressure in said chamber and acting in a direction to lift said valve during fuel discharge, and means for limiting the maximum extent of valve movement, the ratio of the volume of maximum displacement of said pintle to the maximum volume of fuel per injection coming within a range of from 0 to 1.

13. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge passage, an outwardly opening spring-seated valve controlling said inlet passage, and a pintle movable with said valve and coacting with said discharge passage to define a restricted fuel discharge orifice, the ratio of the weight of the moving parts of the nozzle affecting inertia to the weight of the maximum quantity of fuel per injection coming within a range of from 1 to 25.

14. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge bore, an outwardly facing annular fixed valve seat formed in said passage in axial alignment with said bore, a pintle reciprocable in said bore and having a maximum diameter within a range of from .040 inch to .120 inch coacting with said bore to define an annular minimum discharge orifice, an outwardly opening movable valve seat integral with said pintle and coacting with said fixed seat to define an outwardly opening valve controlling said passage and having a valve opening pressure area exposed to said passage, said pintle having a pressure area at the outlet side of said valve and adapted to act in a direction to lift said valve in response to the fuel pressure, the ratio of said valve opening area to said last-mentioned pressure area coming within a range of from .5 to 1, the ratio of the volume of the fuel space between said valve and said orifice to the minimum volume of fuel per injection coming within a range of from 0 to 1, an axial shank on said pintle and extending through said fixed seat, the ratio of the transverse area of said shank at said valve to the area circumscribed by the

inner circumference of said fixed seat coming within a range of from .2 to .3, and spring means acting on said shank at the inlet side of said valve in a direction to close said valve.

15. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge bore, an outwardly facing annular fixed valve seat formed in said passage in axial alignment with said bore, a pintle reciprocable in said bore and having a maximum diameter within a range of from .040 inch to .120 inch coacting with said bore to define an annular discharge orifice, an outwardly opening movable valve seat integral with said pintle and coacting with said fixed seat to define an outwardly opening valve controlling said passage and having a valve opening pressure area exposed to said passage, said pintle having a pressure area at the outlet side of said valve and adapted to act in a direction to lift said valve in response to the fuel pressure, the ratio of said valve opening area to said last-mentioned pressure area coming within a range of from .5 to 1, the ratio of the volume of the fuel space between said valve and said orifice to the minimum volume of fuel per injection coming within a range of from 0 to 1, and spring means acting on said pintle in a direction to close said valve.

16. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge bore, an outwardly facing annular fixed valve seat formed in said passage in axial alignment with said bore, a pintle reciprocable in said bore and having a maximum diameter within a range of from .040 inch to .120 inch coacting with said bore to define an annular discharge orifice, an outwardly opening movable valve seat integral with said pintle and coacting with said fixed seat to define an outwardly opening valve controlling said passage and having a valve opening pressure area exposed to said passage, said pintle having a pressure area at the outlet side of said valve and adapted to act in a direction to lift said valve in response to the fuel pressure, the ratio of said valve opening area to said last-mentioned pressure area coming within a range of from .5 to 1, and spring means acting on said pintle in a direction to close said valve.

17. In a fuel injection nozzle, in combination, a tip casing having a fuel inlet passage and a discharge bore, an outwardly facing annular fixed valve seat formed in said passage in axial alignment with said bore, a pintle reciprocable in said bore and having a maximum diameter within a range of from .040 inch to .120 inch coacting with said bore to define an annular discharge orifice, an outwardly opening movable valve seat integral with said pintle and coacting with said fixed seat to define an outwardly opening valve controlling said passage, the ratio of the volume of the fuel space between said valve and said orifice to the minimum volume of fuel per injection coming within a range of from 0 to 1, an axial shank on said pintle and extending through said fixed seat, the ratio of the transverse area of said shank at said valve to the area circumscribed by the inner circumference of said fixed seat coming within a range of from .2 to .3, and spring means acting on said stem at the inlet side of said valve in a direction to close said valve.

18. In a fuel injection nozzle, in combination, a tubular tip casing having a closed end wall with an axial discharge bore opening there-through and formed with a counterbore in the inner end presenting an inwardly facing annular stop shoulder, a tubular valve seat member removably disposed in said casing and having an

outer end wall engaging said first mentioned wall and formed with a valve inlet passage in axial alignment with said bore, a spherical fixed annular valve seat formed in said last mentioned wall at the outlet end of said passage, the inlet end of said passage being flared inwardly from said seat, a pintle having a cylindrical stem slidable in said bore and an axial shank extending inwardly through said passage, a movable spherical annular valve seat formed on the inner end of said stem and coacting with said fixed seat to define an outwardly opening valve for controlling said passage, spring means in said seat member acting on said shank in a direction to close said valve in opposition to the pressure of the fuel, the outer end of said pintle being formed with a peripheral land area and a contiguous inwardly tapered control cone movable progressively across the outlet edge of said bore in the opening movement of said valve and coacting therewith to define an annular discharge orifice, and a peripheral abutment shoulder on said stem and movable in said counterbore for engagement with said stop shoulder to limit the height of rise of said valve.

19. In a fuel injection nozzle, in combination, a tubular tip casing having a closed end wall with an axial discharge bore opening there-through, a tubular valve seat member slidably disposed in said casing and having an outer end wall engaging said first mentioned wall and formed with a valve inlet passage in axial alignment with said bore, a spherical fixed annular concave valve seat formed in said last mentioned wall at the outlet end of said passage, the inlet end of said passage being flared inwardly from said seat, a pintle having a cylindrical stem slidable in said bore and an axial shank extending inwardly through said passage, a movable spherical annular convex valve seat formed on the inner end of said stem and coacting with said fixed seat to define an outwardly opening valve for controlling said passage, and spring means in said seat member acting on said shank in a direction to close said valve in opposition to the pressure of the fuel.

20. In a fuel injection nozzle, in combination, a tubular tip casing having a closed end wall with an axial discharge bore opening there-through and formed with a counterbore in the inner end presenting an inwardly facing annular stop shoulder, a tubular valve seat member slidably disposed in said casing and having an outer end wall engaging said first mentioned wall and formed with a valve inlet passage in axial alignment with said bore, a fixed annular valve seat formed in said last mentioned wall at the outlet end of said passage, a pintle having a cylindrical stem slidable in said bore and an axial shank extending inwardly through said passage, a movable annular valve seat formed on the inner end of said stem and coacting with said fixed seat to define an outwardly opening valve for controlling said passage, spring means in said seat member acting on said shank in a direction to close said valve in opposition to the pressure of the fuel, and a peripheral abutment shoulder on said stem and movable in said counterbore for engagement with said stop shoulder to limit the height of rise of said valve.

21. In a fuel injection nozzle, in combination, a tip casing having a closed end wall with an axial discharge bore opening there-through and formed with a counterbore in the inner end, an internally longitudinally splined sleeve fitted in

said counterbore and being formed with a counterbore presenting a stop shoulder, a tubular valve seat member slidably disposed in said casing and having an outer end wall engaging said first mentioned wall and formed with a valve inlet passage in axial alignment with said bore, a fixed annular valve seat formed in said last mentioned wall at the outlet end of said passage, a pintle having a cylindrical stem slidable in said bore and said sleeve and an axial shank extending inwardly through said passage, a movable annular valve seat formed on the inner end of said stem and coacting with said fixed seat to define an outwardly opening valve for controlling said passage, spring means in said seat member acting on said shank in a direction to close said valve in opposition to the pressure of the fuel, means in said seat member for limiting the height of rise of said valve, and a peripheral safety abutment shoulder on said stem and movable in said last mentioned counterbore for engagement with said stop shoulder in the event said last mentioned means becomes ineffective.

22. In a fuel injection nozzle, in combination, a tubular tip casing having a closed end wall with an axial discharge bore opening there-through, a tubular valve seat member disposed in said casing and having an outer end wall engaging said first mentioned wall and formed with a valve inlet passage in axial alignment with said bore, a fixed annular valve seat formed in said last mentioned wall at the outlet end of said passage, a pintle having a stem slidable in said bore and an axial shank extending inwardly through said passage, a movable annular valve seat formed on the inner end of said stem and coacting with said fixed seat to define an outwardly opening valve for controlling said passage, an anchor head on the free end of said shank, an apertured hanger disk having a socket loosely receiving said shank and engaging the base of said head for limited relative angulation, a compression spring seated in said member and acting against said disk in a direction to close said valve, and a stop sleeve in said member disposed for engagement by said disk to limit the opening movement of said valve.

23. In a fuel injection nozzle, in combination, a tubular tip casing having a closed end wall with an axial discharge bore opening there-through, a tubular valve seat member removably disposed in said casing and having an outer end wall engaging said first mentioned wall and formed with a valve inlet passage in axial alignment with said bore, a spherical fixed annular valve seat formed in said last mentioned wall at the outlet end of said passage, the inlet end of said passage being flared inwardly from said seat, a pintle having a cylindrical stem slidable in said bore and an axial shank extending inwardly through said passage, a movable spherical

annular valve seat formed on the inner end of said stem and coacting with said fixed seat to define an outwardly opening valve for controlling said passage, spring means in said seat member acting on said shank in a direction to close said valve in opposition to the pressure of the fuel, the outer end of said pintle being formed with a peripheral land area and a contiguous inwardly tapered control cone movable progressively across the outlet edge of said bore in the opening movement of said valve and coacting therewith to define an annular discharge orifice, and positive stop means adapted for engagement to limit the maximum height of rise of said valve.

24. In a fuel injection nozzle, in combination, a casing having a fuel inlet passage and an outlet passage, an outwardly opening spring-seated valve controlling said inlet passage and having a seat defining a valve opening pressure area constituting the sole fuel inlet to said outlet passage, and a pintle movable with said valve and coacting with said outlet passage to define an annular fuel discharge orifice, said pintle having a pressure area at the outlet side of the valve as large as said first mentioned area and responsive during fuel injection to the pressure of the fuel when said valve is moved out of closed position and acting in a direction to lift said valve, said pintle having a valve stem extending in spaced relation through said seat, coiled compression spring means coacting with the inner end of said stem inwardly of said seat and tending to close said valve, and positive stop means adapted to act on said stem for limiting the maximum height of rise of said valve.

25. In a fuel injection nozzle, in combination, a hollow casing having a fuel inlet passage and an outlet passage, an outwardly opening spring-seated valve controlling said inlet passage and having a seat defining a valve opening pressure area constituting the sole fuel inlet to said outlet passage, a pintle movable with said valve and coacting with said outlet passage to define an annular fuel discharge orifice, said pintle having a pressure area at the outlet side of said valve larger than said first mentioned area and responsive during fuel injection to the pressure of the fuel when said valve is moved out of closed position and acting in a direction to lift said valve, a stem on said pintle extending in spaced relation through said seat, coiled compression spring means coacting with the inner end of said stem inwardly of said seat and tending to close said valve, a member anchored to said stem for movement therewith and slidably guided in said casing, and means in said casing presenting a stop shoulder arranged for engagement by said member to limit the height of rise of said valve.

JAMES F. HOFFER.