Dec. 1, 1931. W. F. JOACHIM 1,834,061

FUEL NOZZLE

Filed April 30, 1930

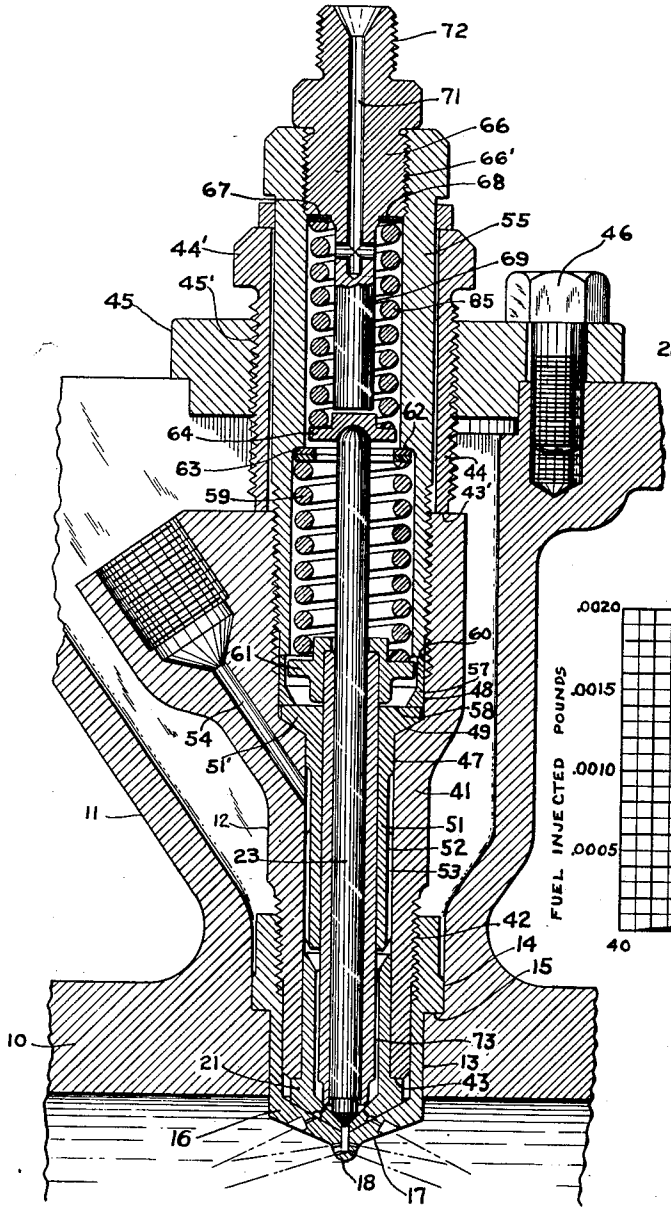


Fig. 2.

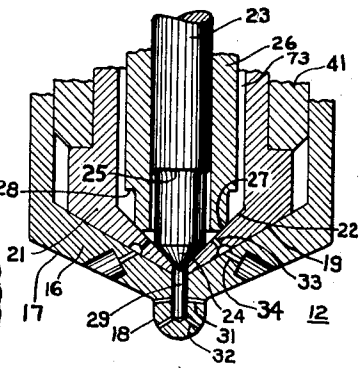


Fig. 3.

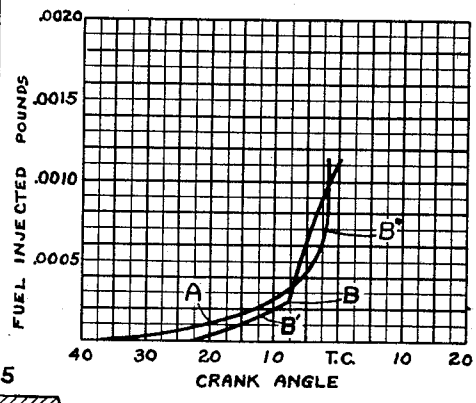


Fig. 1.

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Patented Dec. 1, 1931 1,834,061

UNITED STATES PATENT OFFICE

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FUEL NOZZLE

Application filed April 30, 1930. Serial No. 448,710.

My invention relates to injection valves or atomizers, more particularly to valves for injecting fuel into the cylinders of internal combustion engines and still more particularly to valves which are especially suitable for use with fuel injection systems of the hydraulic pressure injection type, that is, systems wherein the fuel is injected into the engine cylinder by mechanical means, such as a plunger pump, at a relatively high pressure and at an extraordinarily rapid rate. My invention has for an object to provide apparatus of the character designated which shall be capable of so injecting the fuel as to produce lower maximum working pressures within the engine cylinder, increase the combustion efficiency obtaining in the engine cylinder and, consequently, lower the fuel consumption of the engine, as well as increase the mean effective pressure obtaining in the engine cylinder and, consequently, increase the horse power rating of the engine.

These and other objects are effected by my invention as will be apparent from the following description and claims taken in connection with the accompanying drawings, forming a part of this application, in which:

Fig. 1 is a graphic diagram of the process of injecting fuel into the cylinder of an internal combustion engine;

Fig. 2 is a view, in sectional elevation, of one form of injection valve or atomizer arranged in accordance with my invention; and,

Fig. 3 is an enlarged, partial, sectional view of the tip portion of the injection valve shown in Fig. 2.

As is well understood in the internal combustion engine art, a fuel injection system of the hydraulic pressure injection type normally embodies, essentially, a fuel injection pump which is usually of the plunger type and supplied with fuel at a positive but relatively low pressure by a booster pump or supply tank. The fuel injection pump is driven in timed relation with the crank shaft of the engine and has some form of valve means associated therewith capable of rendering the pump periodically effective to discharge the fuel to the injection valve at a relatively high pressure. The fuel injection valve is usually so arranged that it opens periodically in response to the successive discharges of the injection pump and the valve serves to atomize the fuel and to deliver the same into the combustion chamber of the engine. Such systems must be very carefully constructed and arranged in view of the extraordinary requirements in that the pump may be required to periodically and almost instantly develop a pressure as high as 8,000 or more pounds per square inch and to deliver an accurately metered quantity of fuel consistently as required. By way of example, an engine having a nine-inch bore and a twelve-inch stroke may require the periodic delivery, during approximately .003 of a second, of approximately .034 cubic inches of fuel. These figures demonstrate with what exactitude the fuel must be metered and delivered to the engine during each cycle thereof.

As stated heretofore, the fuel injection valve delivers the fuel, received from the injection pump, to the combustion chamber of the engine cylinder. I have found that the combustion efficiency obtaining in the engine cylinder is vitally affected by the manner in which the fuel valve delivers the fuel to the combustion chamber.

In determining the proper action of the fuel injection valve, it has heretofore been customary to take into consideration the amount of work to be performed in a given size of engine cylinder, the form of the combustion chamber, etc. However, if good combustion efficiency is to be obtained, additional factors must be taken into consideration and calculated. Among others, the following factors are given by way of example:

(1) The changing position of the mass center of the air which is under compression

by the piston in the combustion chamber as effected by the movement of the piston. In the present example, the mass center of the air for every five degrees crank angle position of the piston before and after top center during the fuel spray development and the air mixing process have been taken into consideration.

(2) Total time bag, which is the total time from the instant of fuel entry into the combustion chamber until the completion of combustion of every particle of fuel, and which may be divided into several contributing lags as follows:

(*a*) Penetration lag which is the time required for any fuel quantity to reach the air with which it must later mix and burn.

(*b*) Distribution lag which is the time required for the fuel to mix with its air after it has penetrated the required distance into the combustion chamber.

(*c*) Ignition lag which is the time required for the vapor from any fuel particle to become ignited; and,

(*d*) Combustion lag which is the time required for any fuel particle to be completely vaporized and burned.

(3) Coordination of the varying quantities of fuel being distributed with the changing position of the air mass center.

As a result of analyses including the foregoing, as well as many additional conditions, I have found that the fuel should be injected into the engine cylinder approximately as indicated in Fig. 1 in which the angular positions of the crank shaft before and after top center are indicated as abscissa and the rate of fuel injection as ordinates. From the curve indicated by reference character "A", it will be apparent that, in the present example, fuel injection should commence at a position of approximately 35° before top center, depending on engine speed. This rate should then slowly increase until a crank angle approximately 10° before top center is reached, depending on engine speed, when the quantity of fuel injected should increase at a greatly accelerated rate. This curve shows that, in order to obtain the best combustion efficiency in a Diesel engine, the rate of fuel injection at the start of each cycle must be relatively slow but rapidly accelerated near the end of the injection cycle.

Injection of fuel in a manner such as described can not be obtained with fuel injection valves of the character heretofore employed, because these injection valves generally comprise a single fuel passage or nozzle, or a single set of nozzles acting in unison, controlled by a single valve stem opened by the fuel pressure delivered by the injection pump against the force exerted by a single spring. Consequently, instead of obtaining a rate of injection approximating the curve "A", a rate of injection corresponding to an approximately straight line is obtained. Such a straight line characteristic cannot be so inclined as to very closely approximate the curve "A". Consequently, relatively poor combustion efficiency has been obtained with the types of injection valves heretofore employed.

I have, therefore, conceived the idea of providing an injection valve of, what may be termed, the multiple orifice or nozzle type in which the orifices or nozzles have individual valve mechanisms associated therewith which open in response to different fuel pressures, the first or primary orifice or nozzle providing for the early and relatively slow rate of fuel injection and the second or secondary orifice or nozzle being effective, during the latter portion of the fuel injection period, to augment the action of the primary orifice or nozzle so as to provide for a relatively rapid rate of fuel injection during the latter portion of each injection period. By means of such a form of injection valve, an injection characteristic such as indicated by the curve "B", in Fig. 1 is obtainable, the action of the primary orifice or nozzle being indicated by the portion "B′" of the curve while the action of both orifices or nozzles is indicated by the portion "B′′" of the curve. From inspection of Fig. 1, it will be apparent that the curve "B" closely approximates the theoretically ideal curve "A" and, furthermore, it will be apparent that, by employing more than two orifices or nozzles with suitable stems, springs, fuel passages, etc., even a closer approximation can be had.

It is, therefore, a still more particular object of my invention to provide a form of injection valve which is capable of so delivering the fuel into the combustion chamber during each injection period as to so accelerate the rate of fuel delivery as to obtain nearly ideal combustion conditions.

Referring now to the drawings, I show, in Figs. 2 and 4, a cylinder 10 of an internal combustion engine. The cylinder 10 is provided with a projecting portion 11 which forms a receptacle for a fuel injection valve, generally represented at 12. An opening 13 communicates with the interior of the cylinder 10, the opening being preferably provided with a counterbore 14 forming a shoulder 15. Fitting within the opening 13 and seated upon the shoulder 15 is a nozzle 16 having a conical face portion 17 terminating in a centrally-disposed tip 18. The nozzle 16 is provided with an inner conical seat 19 upon which is seated a seat piece 21, the latter being provided with an inner conical seat 22. Extending toward the seat piece 21 is a secondary valve stem 23 provided with a valve face 24 which coacts with the seat 22 of the seat piece. The secondary valve stem 23 is provided with a shoulder or piston portion 25 spaced axially from the valve face.

Surrounding the secondary valve stem 23 is an annular, primary valve stem 26 provided with an annular valve face 27 which also coacts with the seat 22 of the seat piece. The primary valve stem 26 is also provided with a shoulder or piston portion 28 spaced axially from its valve face. Provided axially within the seat piece and the nozzle is a secondary fuel passage 29 arranged to be opened and closed by movement of the secondary valve stem 23. Secondary fuel from the passage 29 is atomized and sprayed into the engine cylinder by a plurality of orifices of such size and spacing as to correctly deliver fuel for the secondary injection. In the present embodiment, I show one form of arrangement wherein there is provided a plurality of upper, circumferentially-spaced and radially-extending orifices 31 and a plurality of lower, circumferentially-spaced and somewhat downwardly-inclined and diverging orifices 32. Provided in the seat piece 21 between the valve faces 24 and 27 are a plurality of circumferentially-spaced, and somewhat downwardly-inclined holes 33 which communicate, with primary orifices 34 also provided in the nozzle. The primary orifices 34 and the secondary orifices 31 are preferably so inclined with respect to each other as to direct the conical fuel spray from the secondary orifices 31 in a plane intersecting the conical primary fuel spray emitted from the primary orifices 34 though this feature may be arranged to suit the special requirements of the engine considered.

The seat piece and the nozzle are retained in relative position by an atomizer body 41. The nozzle surrounds the atomizer body and is secured thereto by screw threads 42, the nozzle serving to clamp the seat piece within the atomizer body by thrusting its shoulder portion 43 against the lower lateral end face of the atomizer body. The seat piece may also be a press fit in the atomizer body. Disposed in abutting relation with the upper lateral face 43′ of the atomizer body is a nut 44 having an external, flat-sided portion 44′ and held in position in the receptacle 11 by a clamp 45. The latter engages the nut 44 by means of screw threads 45′ and is detachably secured to the engine cylinder by some means, such as, for example, a tap bole 46.

The atomizer body is provided with a lower bore 47 and with an upper counterbore 48, the two bores being joined by an internal conical seat 49. Seated in the latter is a flange portion 51′ of a guide bushing 51. The latter projects downwardly within the nozzle body and terminates near the vicinity of the seat piece 21. The guide bushing 51 has a reduced diametral portion 52 and one or more slots or flats which form, with the bore 47 of the body member, an intervening passage 53 arranged to receive fuel delivered through an inlet 54 and to transmit the same to the shoulder or piston face 28 (Fig. 3) of the primary valve stem and to the shoulder or piston face 25 of the secondary valve stem at such times as the primary valve stem is in open position.

The bushing 51 is held in abutting relation with the seat 49 by means of a sleeve 55 screwed into the counterbore 48 of the nozzle body and abutting, through a distance piece 57, with the upper lateral face 58 of the guide bushing. The sleeve 55 is bored out to provide a housing for a compression spring 59 which engages the primary valve stem 26 through a spring carrier 61 freely carried on the upper end of the primary valve stem. The upper end portion of the spring exerts its thrust against a shoulder 62 of the bushing and, preferably interposed between the spring 59 and the shoulder 62, are one or more shims or distance pieces 63 for effecting adjustments of the spring force. The spring 59 serves to hold the primary valve stem 26 to a closed position, that is, the position indicated in Fig. 3. The bore of the distance piece 57 is made relatively larger than the bore of the adjacent end of the sleeve 55 so as to provide a shoulder 60 which coacts with the spring carrier 61 to limit opening movements of the primary valve stem 26.

The upper end of the secondary valve stem 23 is also provided with a spring carrier 64 and a compression spring 65, the latter being retained in the sleeve by a nut 66 threaded to the sleeve, as at 66′. Fitting between the spring 65 and the nut 66 are one or more shims or distance pieces 67 for effecting adjustments of the spring 65. As will be apparent, the spring 65 serves to hold the secondary valve stem 23 to a closed position, that is, the position indicated in Fig. 3. The lift of the secondary valve stem 23 is limited by a stop 69 which depends from the nut 66 and coacts with the spring carrier 64. Fuel which may leak between the relatively movable primary and secondary valve stems as well as the primary valve stem and the guide bushing is relieved through an outlet 71 provided in the nut 66 and having a threaded portion 72 for connecting a drain conduit thereto (not shown).

The operation of the foregoing fuel injection nozzle will now be described. Let it be assumed that fuel is being periodically discharged at a high pressure to the inlet 54 by suitable pumping apparatus in a manner well understood in the art. The fuel pressure is transmitted from the inlet 54 through the space 53 intervening between the bushing 51 and the atomizer body 41 as well as the communicating annular space 73 intervening between the primary valve stem 26 and the seat piece 21 and is imposed upon the shoulder or piston face 28 of the primary valve stem 26. When the fuel pressure rises sufficiently, the force exerted by the spring 59 is overcome

and the primary valve stem 26 is raised, permitting fuel to be discharged through the primary passages 33 and primary orifices 34 into the engine cylinder. The opening movement of the primary valve stem 26 is accurately limited by the spring carrier 61 abutting against the shoulder 60.

After the primary valve stem has opened and primary fuel is being sprayed into the engine cylinder by the primary orifices 34, the increasing pressure of the fuel delivered by the pump is imposed upon the piston face or shoulder 25 of the secondary valve stem 23 and, upon sufficient increase in pressure over and above that which raised the primary valve stem 26, the force of the spring 65 is overcome and the secondary valve stem 23 is raised to permit fuel to enter the passageway 29 and to be sprayed into the cylinder through the secondary orifices 31 and 32. The opening movement of the secondary valve stem 23 is accurately limited by the spring carrier 64 coming into abutting relation with the stop 69. As soon as the fuel pressure in the inlet 54 falls, both springs 59 and 65 act to close their associated valve stems and injection of fuel into the engine cylinder is momentarily interrupted until such time as the fuel pressure in the inlet 54 is again raised.

From the foregoing, it will be apparent that the primary fuel sprays, that is, the sprays discharged through the primary orifices 34 enter the engine cylinder before or ahead of the secondary sprays, that is, the fuel sprayed into the cylinder through the secondary orifices 31 and 32. In the present embodiment, this is accomplished by utilizing such springs and primary stem and secondary stem lifting faces 25 and 28, respectively, as together will cause the primary stem to lift at some particular higher unit fuel pressure as is required by the engine and fuel pump under consideration. For example, the spring associated with the primary valve stem in combination with the primary stem lifting face 28 may be so proportioned as to require a unit fuel pressure of 1800 lbs. per sq. inch to cause the primary stem to lift while the spring associated with the secondary valve stem in combination with the secondary stem lifting face 25 may require a unit fuel pressure of 3000 lbs. per sq. inch to cause the secondary stem to lift.

The primary fuel sprays or orifices 34 preferably have a lesser flow capacity than the secondary orifices 31 and 32 so that the primary orifices first deliver a relatively small quantity of fuel at a relatively slow rate to the engine cylinder, and, after a predetermined period, the secondary valve opens to rapidly accelerate the delivery of fuel, as generally indicated by curve "B" in Fig. 1. In this connection, it is noted that the capacity of the primary orifices 34 is relatively lower than the rate of fuel delivery through the inlet 54 so that, even though the primary orifices 34 are spraying fuel into the engine cylinder, the fuel pressure at such times is increasing so as to cause subsequent opening of the secondary valve stem.

A form of injection nozzle of the character disclosed effects a process of combustion within the cylinder which is such as to both lower the maximum working pressure and to increase the combustion efficiency and consequently the horse power rating of the engine cylinder. In accordance with this process, the primary fuel spray enters the cylinder ahead of the secondary fuel sprays and are normally already burning when the secondary fuel sprays enter the engine cylinder. It should be understood that the processes of this combustion system may be carried out as well in certain cases where the primary sprays need not be actually burning before the secondary sprays enter the engine cylinder but said primary sprays must ignite shortly after the secondary sprays enter the engine cylinder and before the said secondary sprays ignite due to the heat of compression of the cylinder air. The primary fuel sprays serve to uniformly and progressively increase the temperature and pressure obtaining within the combustion chamber of the cylinder, and, inasmuch as the primary injection and combustion generally take place while the engine piston is approaching its top center position, ideal temperature and pressure conditions are produced in the engine cylinder by the time the secondary fuel sprays are admitted. At the time the primary sprays are admitted to the combustion chamber, there is an abundance of air in the combustion chamber in proportion to the amount of fuel admitted so that the primary sprays burn easily and efficiently. In addition, because of the limited quantity of fuel in the primary sprays, which is approximately one-fourth to one-sixth the full load fuel quantity, knocking is avoided.

When the primary fuel sprays are burning, there is local heating of the air in the immediate vicinity of the primary fuel sprays. This heated air naturally expands and serves to compress the relatively cool gas in the remaining or more distant portions of the combustion chamber. In other words, the air which is heated in the vicinity of the primary fuel sprays serves, when it expands, as a fluid piston to force a large portion of the remaining air in the combustion chamber away from the burning primary fuel spray toward the remote portions of the combustion chamber. As a result, adiabatic compression of that portion of the air in the combustion chamber assigned to the secondary fuel sprays is effected prior to the entry of the secondary fuel spray. This adiabatic compression further prepares the air for more rapid ignition and progressive and complete combustion of

the secondary fuel sprays by increasing both the temperature and density of the cylinder air. Of additional importance is the fact that this compression process creates considerable turbulence of the air within the combustion chamber prior to and during the admission of the secondary fuel spray. Furthermore, when the secondary fuel spray is admitted to the engine cylinder, it ignites easily and early because an ignition flame is already provided by the burning primary fuel spray.

As will be apparent from Figs. 2 and 3, the secondary orifices 31 are so inclined, in relation to the primary orifices 34 that the fuel spray admitted through the orifices 31 intersects the primary fuel spray. The secondary fuel spray is therefore progressively ignited by the primary fuel spray.

At commencement of the secondary fuel spray, the air is concentrated in the head end of the cylinder because of the fact that the piston is near its top center position. However, as the pistons move away from the head portion of the cylinder on its working or firing stroke, the air in the combustion chamber is expanded and circulation toward the moving piston is effected. As a result, the air is drawn through the heavy fuel particles discharged from the secondary orifices 31 and 32 and thoroughly commingled therewith.

From the foregoing, it will be apparent that I have evolved a form of injection nozzle which is capable of producing, in the cylinder of an internal combustion engine, a combustion process of a new and improved character and capable of producing more efficient combustion of fuel than the systems heretofore provided. While, in the present embodiment, I show a form of injection nozzle in which the primary and secondary orifices as well as the primary and secondary valve stems are arranged co-axially, nevertheless, it will be apparent that other arrangements may be utilized as my invention contemplates, in its broader aspects, the provision of fuel injection apparatus for an engine cylinder which is capable of so regulating the supply of fuel into the engine cylinder as to provide a relatively slow rate of fuel delivery during the early portion of each injection period and a rapidly accelerated rate of fuel injection during the latter portion of each injection period.

While I have shown my invention in but one form, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various changes and modifications, without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

What I claim is:—

1. In fuel injection apparatus for the cylinder of an internal combustion engine, the combination of nozzle means having first and second spray openings, valve means for controlling the flow of fuel through the first and second spray openings, and means responsive to fuel pressure for opening the first and second valve means successively so as to provide an accelerated rate of fuel delivery into the engine cylinder.

2. In apparatus for periodically injecting fuel into the cylinder of an internal combustion engine, the combination of nozzle means having a relatively small capacity primary nozzle opening and a relatively larger capacity secondary nozzle opening, valve means for controlling the flow of fuel through each nozzle opening, and means responsive to fuel pressure for opening the primary valve means and subsequently the secondary valve means so as to provide an acceleration in the rate of fuel delivery into the engine cylinder during an intermediate portion of each injection period.

3. In fuel injection apparatus for the cylinder of an internal combustion engine, the combination of nozzle means having primary and secondary orifices, valve means associated with the respective orifices for controlling the flow of fuel therethrough, and means responsive to an increase in fuel pressure for opening the primary and secondary valve means in sequence and responsive to a decrease in fuel pressure for closing them simultaneously.

4. In fuel injection apparatus for the cylinder of an internal combustion engine, the combination of nozzle means having a series of nozzle openings of progressively increasing capacities, valve means associated with the respective nozzle openings for controlling the flow of fuel therethrough, and means responsive to increases in fuel pressure for opening the valve means progressively so as to provide for rapid acceleration in the rate of fuel delivery into the engine cylinder during the injection period.

5. In apparatus for periodically injecting fuel into the cylinder of an internal combustion engine, the combination of nozzle means having first and second spray openings, separate valve means associated with the first and second spray openings for controlling the flow of fuel therethrough, said first and second valve means being disposed in concentric relation, and means responsive to increases in fuel pressure for opening the primary valve means and subsequently the secondary valve means so as to provide an acceleration in the rate of fuel delivery into the engine cylinder during an intermediate portion of each injection period.

6. In fuel injection apparatus for the cylinder of an internal combustion engine, the combination of nozzle means having concentrically-arranged first and second circum-

ferentially spaced spray openings, separate valve means associated with the first and second spray openings for controlling the flow of fuel therethrough, said first and second valve means being disposed in concentric relation, means for biasing the respective valve means to closed positions, means responsive to fuel pressure for opening the primary valve means and means responsive to a substantially greater fuel pressure for opening the secondary valve means.

7. In a fuel injection apparatus for the cylinder of an internal combustion engine, the combination of a plurality of circumferentially-spaced orifices for discharging primary fuel and having their respective axes disposed in conical formation, additional circumferentially-disposed orifices disposed interiorly of the primary orifices for discharging secondary fuel, said secondary orifices having their axes intersecting the cone formed by the axes of the primary orifices, valve means associated with the primary and secondary orifices for controlling the flow of fuel therethrough, means responsive to an increase in fuel pressure for actuating the valve means to discharge fuel through the primary orifices and means responsive to a further increase in fuel pressure for actuating the valve means to discharge fuel through the secondary orifices.

8. In a fuel injection apparatus for the cylinder of an internal combustion engine, the combination of a plurality of circumferentially-spaced orifices having their respective axes disposed in conical formation for discharging primary fuel, additional orifices disposed interiorly of the primary orifices for discharging secondary fuel, said secondary orifices comprising a series of circumferentially-spaced orifices having substantially radially-extending axes intersecting the cone formed by the axes of the primary orifices and a second series of circumferentially-spaced orifices having their axes defining a cone located interiorly of and spaced from the cone defined by the axes of the primary orifices, valve means associated with the primary and secondary orifices for controlling the flow of fuel therethrough, means responsive to a predetermined increase in fuel pressure for actuating the valve means to discharge fuel through the primary orifices and means responsive to a further increase in fuel pressure for actuating the valve means to discharge fuel through the secondary orifices.

9. In a fuel injection apparatus for the cylinder of an internal combustion engine, the combination of a plurality of circumferentially-spaced orifices having their respective axes projecting radially outward for discharging primary fuel, a centrally-disposed axially-extending fuel passageway, additional circumferentially-spaced orifices communicating with the central passageway and having their axes projecting radially outward for the discharge of secondary fuel, a centrally disposed, axially movable valve mechanism cooperating with the central fuel passageway for controlling the discharge of fuel by the secondary orifices, a second valve mechanism disposed concentrically about the first valve mechanism for controlling the flow of fuel through the primary orifices, means responsive to a predetermined increase in fuel pressure for opening the valve means associated with the primary orifices, and means responsive to a greater increase in fuel pressure for opening the valve means associated with the secondary orifices.

10. In a fuel injection apparatus for the cylinder of an internal combustion engine, the combination of a nozzle body having an inlet for the admission of fuel, nozzle means provided in the body, said nozzle means including first and second spray openings for the discharge, respectively, of primary and secondary fuel, primary valve means interposed between the fuel inlet and the primary spray openings for controlling the discharge of fuel by the latter, secondary valve means disposed on the side of the primary valve means remote from the fuel inlet for controlling the discharge of fuel by the secondary spray openings, means responsive to a predetermined increase in fuel pressure for opening the primary valve means and means responsive to a further increase in pressure for opening the secondary valve means.

11. In a fuel injection apparatus for the cylinder of an internal combustion engine, the combination of nozzle means having first and second spray openings for the discharge of primary and secondary fuel, respectively, separate valve means associated with the first and second spray openings for controlling the flow of fuel therethrough, means responsive to a predetermined increase in fuel pressure for opening the primary valve means, and means effective upon an opening of the primary valve means and responsive to a further increase in fuel pressure for opening the secondary valve means.

12. In fuel injection apparatus for the cylinder of an internal combustion engine, the combination of a body having an axially extending opening, a nozzle fitting in said opening, a valve seating member disposed within the nozzle, means for admitting fuel to the interior of the seating member, primary and secondary spray orifices provided in the nozzle, said seating member having openings extending therethrough for the passage of fuel to the orifices, a valve disposed in the seating member for controlling the discharge of fuel through the secondary orifice, a second valve disposed in the seating member between the first valve and the fuel admission means for controlling the discharge of fuel

through the primary orifice, and means responsive to fuel pressure for opening the valves and providing for opening of the valve controlling the primary orifice ahead of the valve controlling the secondary orifice.

13. In a fuel injection device for an internal combustion engine, the combination of a body having a fuel inlet, nozzle means secured to the body and having primary and secondary atomizing means, inner and outer independently-movable concentric valve members for controlling, respectively, the discharge of fuel from the inlet to the primary and secondary atomizing means, said inner valve member being longer, axially, than the outer valve member, a spring surrounding the inner valve member and engaging the outer valve member for biasing the same to a closed position, a second spring disposed coaxially with the first spring and engaging the inner valve member for biasing the same to a closed position, the spring engaging the valve associated with the secondary atomizing means being formed to exert a greater unit pressure than the spring engaging the valve associated with the primary atomizing means, whereby sequential opening of the valves is afforded, and means responsive to the pressure of the fuel admitted through the inlet for opening the valves.

14. In a fuel injection device for an internal combustion engine, the combination of a body having a fuel inlet and provided with an axial bore separated by a seat from an interiorly-threaded counterbore, a valve seating member fitting within the end of the bore of the body, a nozzle surrounding the body and clamping the seating member thereto, primary and secondary atomizing means embodied in the nozzle, a bushing arranged in said axial bore and having a flange portion fitting the seat of the body, said bushing cooperating with the bore of the body to provide a passageway from the fuel inlet toward the nozzle, inner and outer concentric valve members movable axially within the bushing and movable axially with respect to each other for controlling, respectively, movement of fuel from the passageway to the primary and secondary atomizing means, piston means provided on each of the valve members for opening the same in response to fuel pressure, a sleeve having threads for engagement with the threads of the counterbore and cooperating with the flange portion of the bushing to maintain the flange portion of the bushing tightly fitted with respect to the seat of the body portion, said sleeve having a counterbore portion providing a shoulder, a compression spring interposed between the shoulder and one of the valve members for biasing the valve member to closed position, a second spring disposed in the bore of the sleeve member and engaging the other valve member, and a member for closing the end of the sleeve and for retaining the latter spring under compression, the spring and piston means associated with the valve of the secondary atomizing means being so formed as to require a greater unit fuel pressure for opening the same than the spring and piston means associated with the valve of the primary atomizing means, whereby sequential opening of the valves is afforded.

In testimony whereof, I have hereunto subscribed my name this 29th day of April, 1930.

WILLIAM F. JOACHIM.