Oct. 20, 1953 J. F. CAMPBELL 2,656,218

SPRAY NOZZLE

Filed July 21, 1949 3 Sheets-Sheet 1

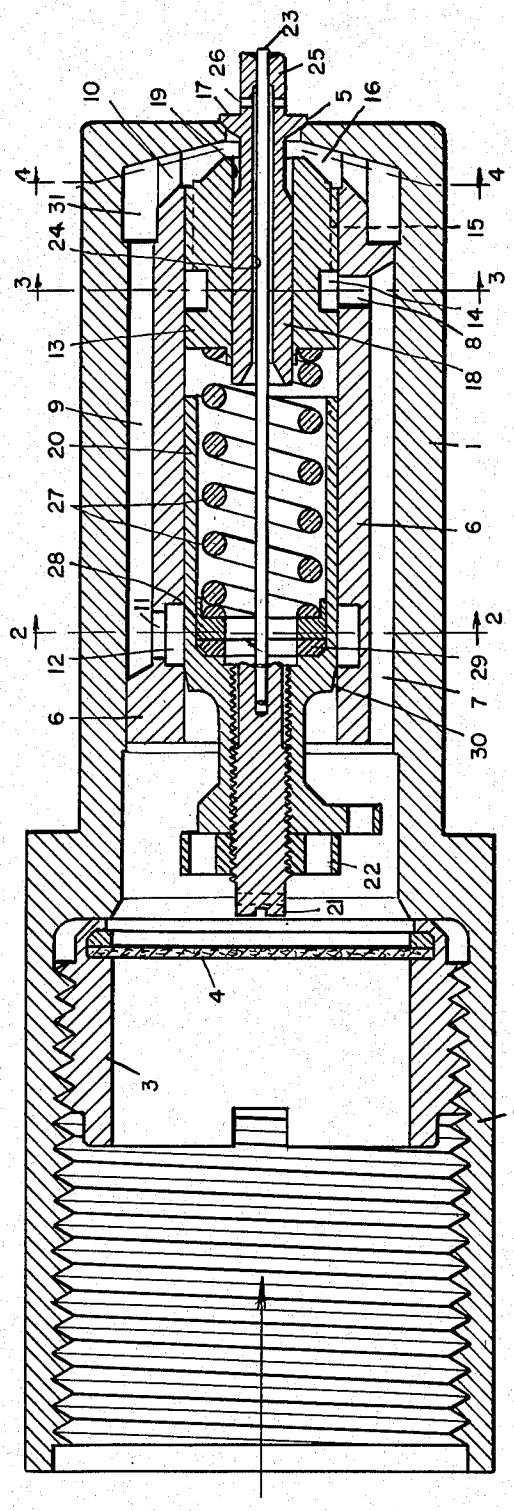


Fig. 1

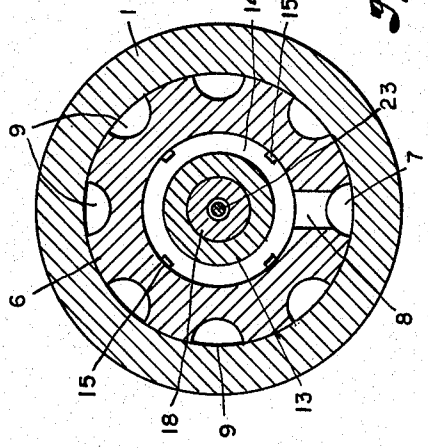


Fig. 3

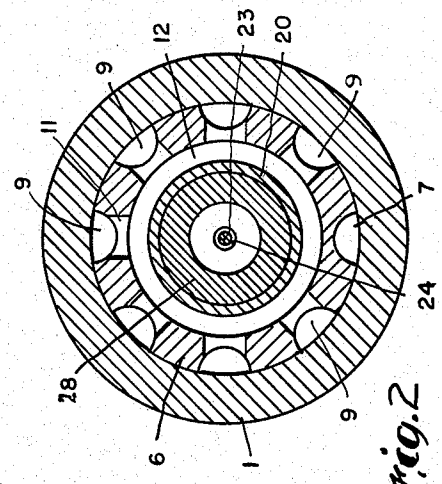


Fig. 2

INVENTOR.
JOHN F. CAMPBELL
BY
Oberlin & Limbach
ATTORNEYS.

Oct. 20, 1953 J. F. CAMPBELL 2,656,218

SPRAY NOZZLE

Filed July 21, 1949 3 Sheets-Sheet 2

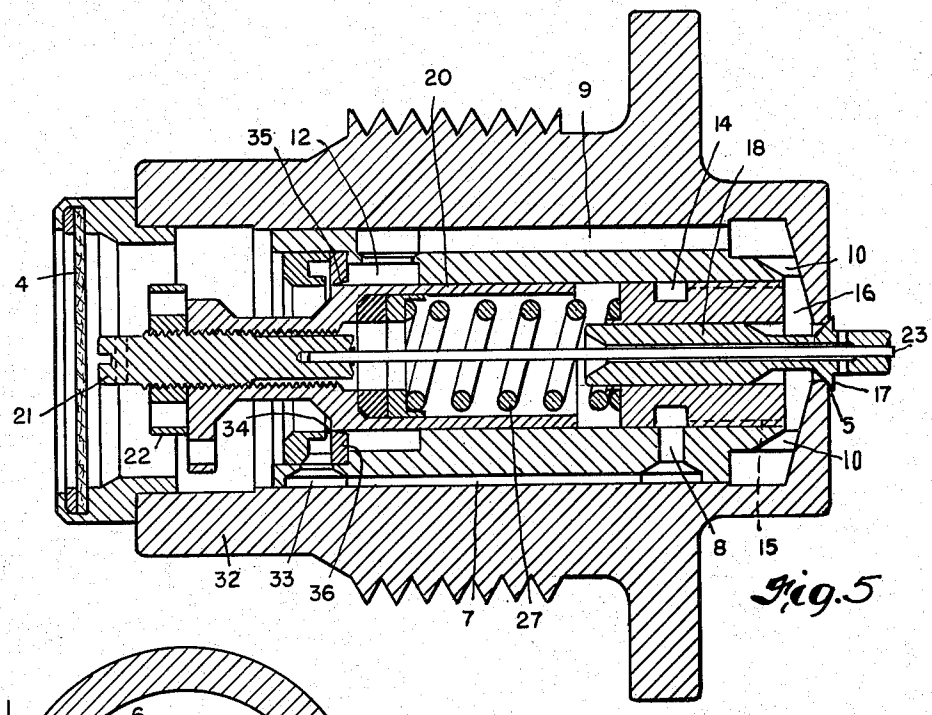


Fig. 5

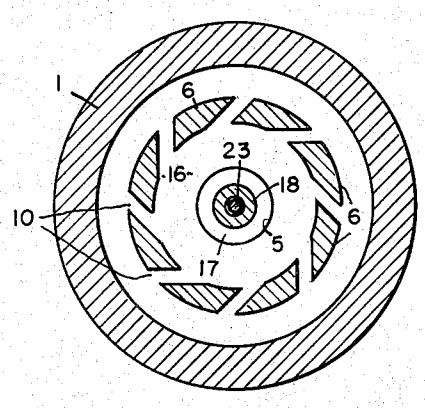


Fig. 4

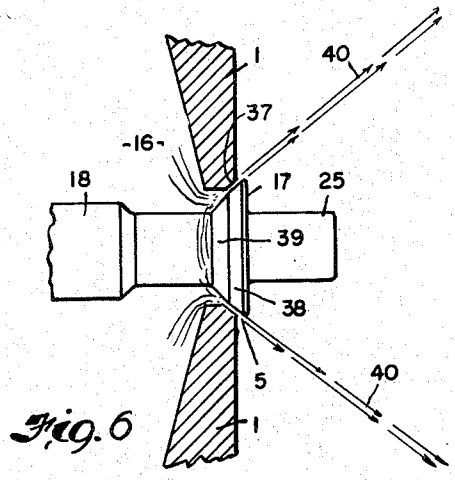


Fig. 6

INVENTOR.
JOHN F. CAMPBELL
BY
Oberlin & Limbach
ATTORNEYS.

Oct. 20, 1953 J. F. CAMPBELL 2,656,218

SPRAY NOZZLE

Filed July 21, 1949 3 Sheets-Sheet 3

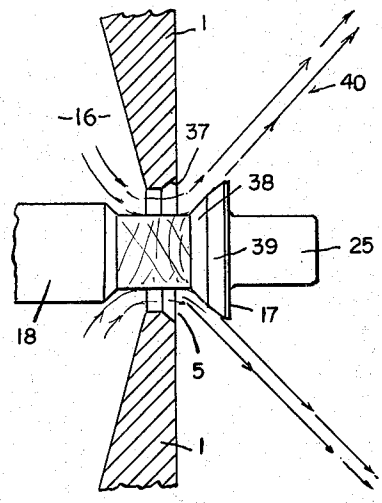


Fig. 7

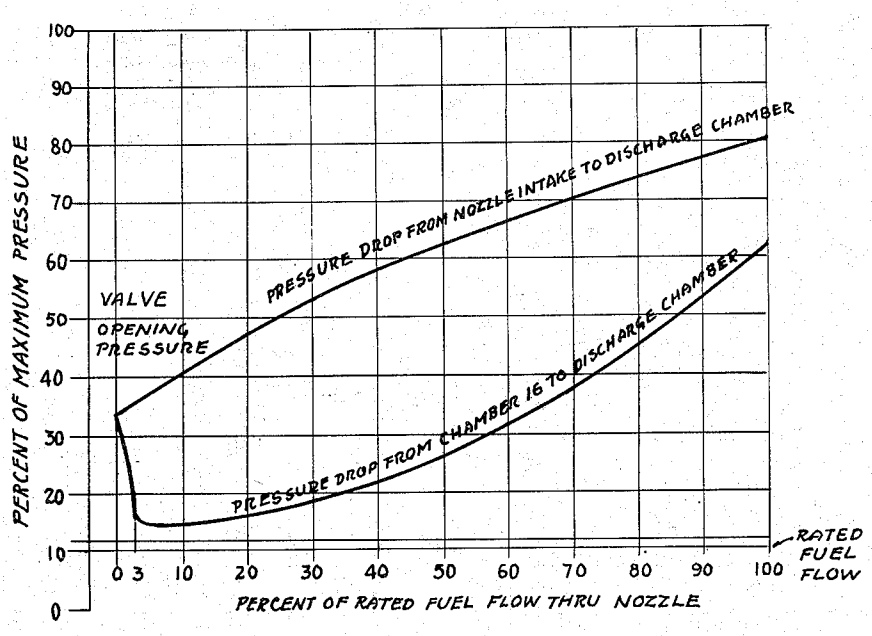


Fig. 8

INVENTOR.
JOHN F. CAMPBELL
BY
Oberlin & Limbach
ATTORNEYS.

Patented Oct. 20, 1953 2,656,218

UNITED STATES PATENT OFFICE

2,656,218

SPRAY NOZZLE

John F. Campbell, Euclid, Ohio

Application July 21, 1949, Serial No. 105,975

25 Claims. (Cl. 299—118)

1

This invention relates as indicated to nozzles and more particularly to nozzles especially adapted for the injection of liquid fuels into combustion chambers of various types of engines.

There are at present several different types of engines employing liquid fuels which require to be injected into the combustion chambers of the same, such engines including the well-known automotive internal combustion engine, diesels, the turbo-jet, prop-jet, and ram-jet engines and the like. While such latter types of engines are at present largely employed in aircraft, it is expected that they will shortly find application in railway locomotives and ships. In certain of such engines it is necessary to provide for a wide range of fuel flow between selected minimum and maximum limits while at the same time maintaining a low over-all pressure drop through the nozzle between the fuel intake manifold and the combustion chamber.

Open orifice type nozzles have been employed in the past in such applications but without any great measure of success, principally because of their limited flow range of approximately 10 to 1. The flow range which must be obtainable for continuously efficient operation of certain of the more modern jet engines is in some cases as much as 125 to 1. The usual open orifice nozzles are not capable of any such range of performance since in such nozzles when the rate of flow is increased by a stated factor the corresponding line pressure will require to be increased by such factor squared. To attempt to provide for any great range of flow with this latter type of nozzle is therefore wholly impracticable as leading to impossibly high line pressures in the upper range of flow.

With closed and/or variable orifice nozzles I have, however, found it possible to obtain a wide range of flow without excessive intake pressures being required to achieve high flow rates. A serious difficulty with this latter type of nozzle, however, is encountered in attempting to meet the rigid specifications generally imposed as to maintenance of a designated angle of spray cone at all operating rates of flow. When the rate of flow drops to a very low level, it becomes most difficult to provide a nozzle of this type which will automatically regulate itself to maintain the desired spray angle.

It is therefore a primary object of my invention to provide a nozzle capable of:

(*a*) A wide flow range,

(*b*) But a small increase in pressure loss from low to high rate of flow,

2

(*c*) Maintaining the spray envelope at a substantially constant angle over such large flow range,

(*d*) Atomizing the liquid with slight penetration, i. e. quickly, before the liquid spray cone extends very far, and to the point where an almost dry vapor is obtained.

(*e*) Automatically closing when the inlet pressure drops below some designated value.

A further object of my invention is to provide such nozzle adapted to prevent escape of liquid at an excessively high rate of flow should the exit valve fail for any reason.

Still another object is to provide such nozzle which may be manufactured at a reasonable cost and which will require a minimum of maintenance and repair.

Other objects of my invention will appear as the description proceeds.

To the accomplishment of the foregoing and related ends, said invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawing setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principle of the invention may be employed.

In said annexed drawing:

Fig. 1 is a longitudinal sectional view of one embodiment of my new nozzle taken along the diameter thereof;

Fig. 2 is a transverse sectional view taken along the line **2—2** on Fig. 1;

Fig. 3 is a transverse sectional view taken along the line **3—3** on Fig. 1;

Fig. 4 is a transverse sectional view taken along the line **4—4** on Fig. 1;

Fig. 5 is a longitudinal sectional view taken along a diameter of another nozzle embodying certain features of my invention;

Fig. 6 is a fragmentary sectional view of the nozzle orifice showing the exit valve but slightly open;

Fig. 7 is a view similar to Fig. 6 but showing the valve relatively widely opened; and

Fig. 8 is a graph comparing the pressure drop between the inlet manifold and the combustion chamber with the pressure drop between the chamber at the inlet side of the exit valve and the combustion chamber at different percentages of rated fuel flow through the nozzle.

Referring now more particularly to said drawing and especially Figs. 1–4 thereof, the embodiment of my invention there illustrated comprises

an outer nozzle body 1 of general cylindrical form having an enlarged base portion 2 internally threaded for securing to the intake manifold (not shown) of an engine. An inner sleeve 3 provided with a filter 4 which may be of wire mesh, for example, is threaded into such base portion 2 of the nozzle. This filter serves to protect the inner parts of the nozzle but does not eliminate the need for the usual filters in the main fuel supply line. The other end of the nozzle body is closed except for a centrally disposed orifice 5. All parts may desirably be of stainless steel, for example.

Press fitted within cylindrical nozzle body 1 is an inner liner 6 having a semi-circular longitudinal groove in its outer periphery forming channel 7 open at one end toward the fuel inlet end of the nozzle. The other end of such channel is closed except for a passage 8 leading radially inwardly through liner 6.

A plurality of similar semi-circular grooves are provided in the outer periphery of such liner to form longitudinal channels 9 which open toward the orifice end of the nozzle through generally tangential swirl slots 10. The other ends of channels 9 communicate through radial passages 11 with an inner annular chamber 12 formed in the inner periphery of cylindrical liner 6.

An exit valve guide 13 is press fitted within cylindrical liner 6 toward the orifice end of the nozzle. Such guide is provided with an annular groove in its outer periphery forming annular chamber 14 positioned to communicate through radial passage 8 with channel 7. A plurality of helical slots (in this case four) in the outer surface of guide member 13 form helical channels 15 leading from annular chamber 14 to the chamber 16 just inside nozzle orifice 5. The parts so far described constitute the fixed or immovable elements of my new nozzle assembly.

A poppet type exit valve member 17 adapted to seat in orifice 5 is provided with a valve stem 18 fitted in cylindrical guideway 19 extending through member 13 in axial alignment with such orifice.

Slidably fitted within liner 6 is a cylindrical shell or piston 20 open toward member 13 and closed toward the fuel inlet end of the nozzle. An adjusting screw 21 passes through such latter end of reciprocable cylinder 20 and is adapted to be secured in adjusted position by means of lock nut 22. A spring steel wire connecting rod 23 extends through central passage 24 in valve stem 18, one end of said rod being bonded, as by low temperature brazing, in the end of screw 21 and the other end being similarly bonded to an outer extension 25 of exit valve 17. Vents 26 are provided in such extension communicating with passage 24 so that the interior of reciprocable cylindrical piston 20 is continuously vented to atmosphere or to the interior of a combustion chamber or other discharge chamber. A compression spring 27 within reciprocable piston 20 bears against the end of immovable guide member 13 and at the other end against washer 28 and adjustment shim 29 interposed in the closed end of such piston.

It will now be apparent that, when piston 20 and its associated parts are reciprocated, exit valve 17 will be reciprocated therewith through the agency of connecting rod 23. A degree of misalignment between such valve and piston is, however, permissible in view of the flexibility of the connecting rod and the clearance allowed

the same. The pressure with which valve 17 is seated in orifice 5 may be regulated first by employment of an appropriate shim 29 and secondly by selection of an appropriate compression spring 27. Further adjustment is obtainable by turning adjusting screw 21, but such screw serves an additional function as explained below.

The shoulder 30 of reciprocable piston 20 is bevelled to provide a variable degree of communication with annular chamber 12 when piston 20 is moved inwardly against compression spring 27. Such reciprocable piston therefore acts as a regulating valve. The setting given adjusting screw 21, in conjunction with the thickness of adjustment shim 29, will determine the fluid pressure required to reciprocate regulator valve 20 to admit fluid past contour 30 into chamber 12.

The operation of my new nozzle may now be understood. Liquid fuel enters the nozzle from the fuel manifold and is discharged through orifice 5 into a relatively low pressure exterior chamber. When the fluid pressure bearing against the end of regulator valve cylinder 20 exceeds that in such exterior chamber by an amount barely sufficient to overcome the preload of spring 27, then exit valve 17 will open. The fluid pressure bearing directly against the much smaller effective area of valve member 17 is of relatively little consequence. This opening of valve 17 permits fuel to flow through channel 7, passage 8, and spiral channels 15 into chamber 16 and past exit valve member 17 into the exterior chamber (normally a combustion chamber which may be at substantially atmospheric pressure or in some cases at pressures considerably in excess of atmospheric). Since the cross-sectional areas of spiral channels 15 are quite small and are selected to achieve a relatively large pressure differential between the fuel inlet end of the nozzle and the exterior chamber into which such fuel is discharged thereby, sufficient pressure is built up effective to move valve 20 and open exit valve 17 to a relatively large extent. As a consequence, the fluid pressure bearing against regulator valve 20 is sufficient to shift the latter to move exit valve 17 from its seat in orifice 5 to a degree much greater than would be obtained by the action of fluid pressure bearing against the inner side of valve member 17. The area of the end of regulator valve 20 is, of course, considerably greater than the effective inner area of valve member 17. Helical channels 15 give the fuel a high spinning rate in chamber 16 even at low fuel flows and excellent atomization in the fuel spray envelope is obtained even at such low flows. The spinning inertia of fuel particles in the envelope formed at the opening of exit valve 17 causes such particles to break away and disintegrate the envelope into a finely atomized mist which then further disintegrates into a relatively dry vapor.

Constricted helical channels 15 prevent a high fluid pressure developing in chamber 16 when the exit valve has been thus initially rather widely opened, and accordingly the initial fluid discharge of the nozzle will be at a relatively low rate. Such constricted helical channels likewise ensure that intake pressure is maintained against regulator valve member 29.

As the rate of fuel flow is increased, regulator valve 20 is gradually shifted from left to right as viewed in Fig. 1, bringing bevelled shoulder 30 past the edge of chamber 12. Fuel accordingly enters such chamber to an increasing extent as

such valve opens and passes therefrom through channels 9 and swirl slots 10 into chamber 16 and thence out through orifice 5. Exit valve 17 has, of course, been correspondingly opened as regulator valve 20 was opened. There continues to be a certain amount of fuel flow through channel 7 and spiral channels 15, but this soon becomes inconsequential when compared to the very much larger flow entering through chamber 12 and passing through channels 9.

Contour 30 is selected so that at maximum rated fuel flow the pressure drop between annular chamber 31 and chamber 16 will be as low as possible and still afford sufficient swirling action through slots 10 to provide satisfactory atomization of the fuel at the orifice. Such "bevelled" contour need not necessarily be a straight line and other curves will be employed when suitable. Swirl slots 10 accomplish the same result at higher rates of flow as do spiral channels 15 at low fuel flow, but the pressure loss through slots 10 is much less since they are of relatively large cross-section. Instead of providing angularly disposed slots 10 to obtain the desired swirling action, the channels 9 may themselves be somewhat helical in conformation.

Reference may now be had to Fig. 5 of the drawing showing another embodiment of my invention generally similar to the Fig. 1 form described above but including certain modifications. The valve body 32 is exteriorly threaded to permit the same to be inserted in a correspondingly threaded opening in communication with the fuel inlet manifold. The general internal construction of such nozzle is similar to that shown in Fig. 1 and accordingly need not be again described, like parts being identified by like numerals. The intake end of channel 7 instead of opening directly into the inlet end of the nozzle communicates with an annular chamber 33 having a narrow inlet port 34 in its inner periphery adapted to be closed by axially reciprocable cylindrical valve member 20. Instead of providing a contoured or bevelled shoulder on regulator valve 20 for regulating the admission of fluid to annular chamber 12, a corresponding contour 35 is provided on the inner periphery of ring 36, accomplishing the same result. This nozzle construction embodies a safety feature in that when operating at a low flow rate, should exit valve member 17 break away or become detached, spring 27 would then be enabled to move regulator valve 20 to the left, cutting off fuel flow to both annular chamber 12 and annular chamber 33. This result is accomplished as follows; the adjusting screw may be set so that when exit valve member 17 is seated in the nozzle orifice regulating valve 20 will be effective to close both port 34 and port 12. Consequently, until the line (intake) pressure reaches a predetermined minimum there will be no fluid flow through the nozzle at all. When such pressure is raised sufficiently to move regulating valve member 20 slightly, exit valve 17 will be opened and port 34 cleared, at least in part, permitting limited flow to orifice 5. With prior closed type nozzles, should the exit valve member break away when set for low fuel flow, a greatly increased flow from such nozzle would result, causing a local hot spot. Such "hot spots" are very undesirable in certain types of engines where uniform heating is important. In my new nozzle, however, described above, should the exit valve member 17 break away when such latter valve is closed, it is obvious that spring 27 will be operative to shift regulator valve member 20 still further to the left (Fig. 5), maintaining ports 34 and 12 closed. When exit valve 17 is slightly open at the time of such failure, much the same result will occur. With nozzle orifice 5 no longer blocked, the pressure drop from the fluid intake end of the nozzle to chamber 16 within such orifice is consequently increased, tending to cause a very large percentage increase in fluid flow, but the resultant slight decrease in fluid pressure against valve member 20 permits the latter to shift to the left and close or further constrict the ports so that any substantial increase in flow is very brief. As pressure then builds up in the inlet end of the nozzle, port 34 will again open somewhat, but the flow rate through the nozzle will be subnormal and thus avoid damage to the serviced parts.

Should exit valve member 17 be lost when the nozzle is already discharging at a high rate the mechanism will not normally be effective to close the ports but this is of relatively little consequence since there is no percentage increase in rate of flow possible at all comparable to that which would otherwise occur when operating at a very low flow rate. A local disproportionately hot spot will therefore not result.

Referring now more particularly to Figs. 6 and 7, it will be noted that nozzle orifice 5 is provided with a bevelled valve seat 37 adapted to seat the correspondingly bevelled surface 38 of exit valve 17. When such valve is only slightly opened as shown in Fig. 6, the swirling fuel is discharged through the orifice at an angle determined by such parallel spaced seat portions 37 and 38. If the valve parts are provided with such seats only, however, it is found that at high flow rates the fuel envelope discharged from the orifice will assume a rounded or "umbrella" shape instead of holding to the desired conical form as obtained at low fuel flow. The general result of this effect is equivalent to reducing the angle of the conical fuel envelope and such change of angle is not tolerated by present-day engine specifications.

I have found that by providing a double angle on the inner face of the exit valve 17, thereby providing a second bevelled surface 39 of more obtuse conical contour (i. e., of greater vertex angle), the angle of the spray envelope 40 will be determined by whichever surface 38, 39, is more nearly juxtaposed to seat 37. Consequently, as shown in Fig. 7, when valve 17 is relatively widely opened with a large fuel flow passing through nozzle orifice 5, the angle of the conical spray envelope is relatively wide near its apex, thereby counter-balancing the tendency to form a rounded shape and maintaining the desired angle within prescribed limits. A succession of more than two such conical surfaces of increasing vertex angles may be provided or a continuous curved surface may be utilized to obtain much the same effect.

Referring now to Fig. 8 of the drawing, the figure graphically compares the over-all pressure drop from the nozzle intake to the discharge chamber (ordinarily a combustion chamber) with the pressure drop from chamber 16 (just within the exit valve) to such discharge chamber. The former determines the degree to which the exit valve will be opened and the latter determines the character of the spray cone obtained. At a predetermined intake pressure the exit valve 17 opens, fluid flow passing through channel 7 and helical channels 15 to the orifice 5. As above explained, the intake pressure acting on the relatively large area of regulating

valve 20 serves to open exit valve 17 quite rapidly at first, overcoming any tendency of the latter to stick, but the fluid flow is nevertheless small due to the limited capacity of restricted helical channels 15. To increase the rate of flow therethrough by a stated factor would require that the corresponding line pressure be increased by such factor squared. Consequently, in the low operating range, when there is a slight increase in line pressure, the exit valve will be proportionately opened but there will be little increase in the fluid flow through channels 15 to such valve. Upon substantial increase in the line (intake) pressure, however, regulating valve 20 is further shifted to begin admitting fluid past contour 30 to port 12, by-passing channels 15. Flow through channels 9 soon becomes predominant and the pressure drop between chamber 16 and the discharge chamber increases, while the pressure drop through the entire nozzle (upper line of graph) increases at a substantially less rapid rate than before.

In other words, the pressure drop through the entire nozzle is seen to increase at quite a rapid rate throughout the first 15% of the flow range. This results from the fact that the only liquid flow is through restricted helical channels 15. This pressure is applied directly to the relatively large area of valve member 20, causing correspondingly rapid opening of exit valve 17 even though the liquid flow is still rather low. Good atomization is thus obtained whereas, if liquid pressure against valve 17 were relied upon to open the latter, such valve would not be lifted sufficiently from its seat initially to provide the desired conical fuel envelope at the nozzle orifice. Instead, the fluid would at first tend to emerge in the form of fine jets or "strings," an unacceptable condition which usually occurs when the valve has been lifted on the order of only .001 inch. By way of contrast, conventional closed nozzles require a very considerable proportionate change in fuel flow when operating at a low rate before the pressure is raised sufficiently properly to open the exit valve.

When 3 to 4% of rated flow is attained, valve member 20 will have moved in sufficiently to cause shoulder contour 30 to pass the edge of port 12 and therefore begin to admit liquid to passages 9. When the fuel flow passes about 15% of rated capacity (see graph, Fig. 8) the rate of increase in pressure drop through the entire nozzle as flow increases is seen to diminish, due to the shape of contour 30 which permits increasing flow to chamber 12 and passages 9. While such contour may be selected to afford desired nozzle characteristics, it is usually designed to admit a steadily increasing flow to port 12 as the exit valve is opened so that the angle of the spray cone may be maintained relatively constant at all rates of flow.

When the exit valve is quite wide open and the fluid flow is in the upper 40% or so of the flow range, the shape of the exit valve member 17 seat portion ceases to have much effect on the size of the exit valve opening although still affecting the shape of the spray cone. The valve stem and orifice 5 together now define the annular opening through which the fluid exits. Since, at this stage, it becomes impossible further to enlarge the effective exit valve opening, contour 30 may be selected to admit fluid to port 12 at an increasing rate as valve 20 moves in under the effect of increasing intake pressure. This compensates for the fact that the exit valve

opening does not simultaneously become further enlarged. Alternatively, the valve stem of valve member 17 might be tapered inwardly to modify the size of the exit valve opening but since the nozzles are often very small it is desirable that the stem should not be unduly weakened. By properly modifying contour 30 it is possible to obtain a relatively large increase in flow as a result of a slight increase in pressure in the upper range.

It will accordingly be seen that I have provided a novel nozzle construction capable of a wide flow range but maintaining uniform spray characteristics throughout such range. Such nozzle is automatic in operation, opening only when a predetermined minimum operating pressure is reached and closing when the pressure drops below such point. Proper swirling action is obtained at both high and low rates of flow and the discharge angle of the conical spray envelope can be maintained within prescribed narrow limits. In case of failure of the exit valve, as by separation and loss of valve member 17, damage to the parts serviced may be avoided by resultant automatic regulation of the flow control valve.

Certain features of my invention, such as the by-pass arrangement for regulating fuel flow, may also be employed to advantage in open type nozzles although not achieving all the desirable results I obtain in my preferred form of closed type nozzle. Various liquids such as water, and gases, may be handled by my new nozzle but such nozzle is particularly adapted for employment with liquid fuels such as fuel oil, kerosene, gasolene, and the like.

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

I therefore particularly point out and distinctly claim as my invention:

1. In a liquid fuel injection nozzle having a cylindrical body portion threaded at one end for connection with an intake manifold and provided with a relatively small exit orifice in its other end, an inner cylindrical liner press-fitted within said body portion, a third cylindrical member of substantially less length than said liner press-fitted within said liner adjacent such nozzle orifice but spaced therefrom, an annular chamber in said third member, a plurality of small helical channels leading from said chamber to a chamber immediately communicating with such nozzle orifice, a longitudinally extending channel in said liner leading from the intake end of said nozzle to said annular chamber, a cylindrical valve member mounted for reciprocation within said liner, the end of said cylindrical valve member toward such orifice end of said nozzle being open and the end toward the intake end of said nozzle being closed, an adjusting screw threaded axially through such closed end of said member, means operative to lock said screw in adjusted position, a valve stem reciprocable in said third press-fitted cylindrical member axially of such orifice, an exit valve member carried by said stem adapted to seat in and close such orifice, said valve member and such orifice having cooperative conical seating surfaces, with a conical surface of greater vertex angle on said exit valve member immediately adjacent such seating surface thereon and between such seating surface and said stem, said stem and exit valve member

having a bore axially therethrough, a flexible spring rod inserted in said bore with clearance relative to the wall of the latter and connected at its ends to said screw and exit valve member respectively, whereby said cylindrical valve member and exit valve member are joined for reciprocation in unison, said exit valve member having an opening venting such bore to the exterior of said nozzle, an adjustment shim within said cylindrical valve member against the closed end of the latter, a coiled compression spring interposed between said shim and the adjacent end of said press-fitted third cylindrical member normally operative to hold said exit valve member firmly seated in such orifice, an annular chamber in the inner periphery of said liner near the closed end of said cylindrical valve member and normally closed by the outer cylindrical surface of the latter, one of such surfaces of said liner and said cylindrical valve member being peripherally beveled on desired contour adjacent said annular chamber in said liner but toward the intake end of said nozzle, whereby, upon movement of said cylindrical valve member under influence of fluid intake pressure to open said exit valve, such beveled contour will be effective after predetermined movement to admit an increasing flow of fluid to said annular chamber in said liner, a plurality of channels extending longitudinally through said liner from said annular chamber therein and communicating with a radially outer annular chamber in the orifice end of said nozzle, and generally tangentially arranged slots leading from said last-named chamber to such chamber immediately within such exit orifice to impart a swirling action to the escaping fluid.

2. In a liquid fuel injection nozzle having a fuel intake end adapted for connection with an intake manifold and a relatively small exit orifice in its other end, a channel extending longitudinally from the intake end of said nozzle to an annular chamber therein, a plurality of small helical channels leading from such chamber to a chamber immediately interiorly of such exit orifice, a cylindrical valve member mounted for reciprocation in an inner chamber axially within said nozzle, a valve stem within said nozzle reciprocable axially of such orifice, an exit valve member carried by said stem adapted to seat in and close such orifice, said valve and such orifice having cooperative conical seating surfaces, with a conical surface of greater vertex angle on said exit valve member immediately adjacent such seating surface thereon and between such seating surface and said stem, means interconnecting said exit valve member and cylindrical valve member for axial reciprocation together, said stem and exit valve member having a bore therethrough adapted to vent the inner chamber closed by said cylindrical valve member, a compression spring interposed between said latter valve member and the end of such latter chamber effective normally to hold said exit valve firmly seated in said orifice, an annular chamber surrounding said cylindrical valve member and normally sealed thereby, one of the opposed surfaces of said cylindrical valve member and such inner chamber being peripherally beveled on desired contour adjacent said last-named annular chamber toward the intake end of said nozzle, whereby, upon movement of said cylindrical valve member under influence of fluid intake pressure thereon to open said exit valve, such beveled contour will be effective after predetermined movement to admit an increasing flow of fluid to said annular chamber surrounding said cylindrical valve member, and a plurality of channels extending longitudinally of said nozzle from said latter annular chamber and communicating with the chamber immediately interiorly of such exit orifice by means of angularly disposed swirl slots, said last-named channels and slots being dimensioned for much greater fluid flow therethrough than the aforesaid helical channels.

3. In a nozzle having a fluid intake end and a relatively small exit orifice in its other end, a plurality of small helical channels in communication with such intake end and leading to a chamber immediately within such exit orifice, a regulating valve member axially reciprocable in a chamber in said nozzle toward the intake end of the latter, an annular chamber normally closed from the nozzle intake by the outer periphery of said valve member, an exit valve member adapted to seat in and close such nozzle exit orifice, means joining said regulating valve member and said exit valve member for movement in unison, resilient means adjustably acting on said regulating valve member normally to hold said exit valve member seated in such orifice, and a plurality of large channels leading from said annular chamber longitudinally of said nozzle and communicating through angularly disposed swirl slots with such chamber immediately within such exit orifice, one of the opposed surfaces of said regulating valve member and its enclosing chamber being peripherally beveled adjacent said annular chamber toward the intake end of said nozzle, whereby, upon movement of said regulating valve member under influence of fluid intake pressure thereon to open said exit valve against the action of said resilient means, such beveled contour will be effective after predetermined movement to admit an increasing fluid flow to said annular chamber.

4. In a nozzle having a fluid intake end and an exit orifice end, a constricted helical channel leading from such intake end to such exit end adapted to deliver a small swirling fluid flow at such orifice, an exit valve member adapted to seat in and close such orifice, an annular chamber opening at its inner periphery to the interior of the intake end of said nozzle, a cylindrical regulating valve member reciprocable axially within said nozzle and adapted to close such opening of said annular chamber, means connecting said two valve members for reciprocation in unison, resilient means acting on said regulating valve member normally to hold said exit valve member seated in such orifice and said annular chamber closed, and large channelways leading from said annular chamber and communicating through angularly disposed outlets with such exit orifice, said channelways being adapted to deliver a much larger fluid flow to such orifice than said helical channel, one of said regulating valve member and the inner peripheral surface of said nozzle adjacent the intake side of said annular chamber being beveled to admit an increasing fluid flow to said annular chamber after predetermined movement of said regulating valve member toward the orifice end of said nozzle under influence of fluid intake pressure thereagainst, thereby correspondingly raising said exit valve member from its seat in such orifice.

5. In a nozzle having a fluid intake end and an exit orifice end, a small channel leading from such intake end to such exit end and adapted to deliver a swirling fluid flow at such orifice, an exit valve member adapted to seat in and close

such orifice, a second much larger channel leading from such intake end to such exit end and adapted to deliver a swirling fluid flow at such orifice, a second axially reciprocable valve member adapted to close said second channel, means joining said two valve members for reciprocation in unison, and resilient means urging said second valve member to close said second channel and seat said exit valve member in such orifice, said second valve member being arranged relative to said second channel for predetermined movement to open said exit valve member to a limited extent prior to initiating opening of said second channel, and said second valve member having much larger area subject to fluid pressure thereagainst than said exit valve member.

6. In a spray nozzle having an intake end and a discharge nozzle, a large and a small passage leading from the intake end of such nozzle each adapted to deliver a swirling fluid flow at the nozzle discharge orifice, a regulating valve member arranged for reciprocation in response to nozzle intake pressure operative to open said large passage as such pressure increases and close said passage when such pressure falls below a predetermined figure, a poppet exit valve member for such orifice connected to said regulating valve member for reciprocation therewith, and resilient means urging said exit valve member and regulating valve member to closed positions.

7. In a spray nozzle, a large and a small passage each adapted to deliver a swirling fluid flow at the nozzle discharge orifice, a slide valve member reciprocable in response to nozzle intake pressure operative to open said large passage as such pressure increases, and an externally seated outwardly opening exit valve member for such orifice connected to said first valve member for movement therewith and having a smaller area subject to fluid pressure thereagainst, said slide valve member being arranged for appreciable reciprocation before thus opening said large passage.

8. In a nozzle having an exit orifice, a large and a small passage each leading from the intake end of such nozzle to such orifice, a regulating valve member operative to open said large passage in response to increase in fluid intake pressure, and an exit valve member for such orifice connected with said regulating valve member for movement therewith, said exit valve member being arranged upon reciprocation to open such exit orifice before said regulating valve member opens said large passage.

9. In a nozzle having an exit orifice, a small passage and a much larger passage each leading from the intake end of such nozzle to such orifice, a regulating valve member operative to open said larger passage in response to increase in fluid intake pressure and to close said larger passage when such pressure falls below a predetermined figure, and a separate vent passage leading from a cavity behind said regulating valve member to the exterior of said nozzle to facilitate opening movement of said valve member.

10. In a nozzle having an exit orifice, a small and a large passage each leading from the intake end of said nozzle to such orifice, a regulating valve operative to open both such channels successively under influence of increasing intake pressure, means urging said valve to closed position, and an exit valve member for such orifice connected with said regulating valve for opening and closing movement in synchronism therewith.

11. In a nozzle having an exit orifice, a passage leading from the intake end of said nozzle to such orifice, an axially reciprocable regulating valve member adapted to open said passage under the influence of fluid intake pressure when such pressure exceeds a predetermined figure and to close said passage when such pressure drops below such figure, an exit valve member adapted to seat in such orifice, means connecting said valve members for reciprocation in unison, and resilient means urging said regulating valve member to closed position, said exit valve member and such orifice having cooperative frustroconical seating portions and said exit valve member having a radially inner annular surface lying at a greater angle to the axis of said member than such seating portion on said member and adapted to oppose such seating portion of such orifice when such exit valve is widely opened.

12. In a spray nozzle, a large and a small passage each adapted to deliver a swirling fluid flow at the nozzle discharge orifice, a valve member reciprocable in response to nozzle intake pressure operative successively to open said small passage and said large passage as such pressure increases, an exit valve member reciprocable into and out of seating engagement in such orifice, a longitudinally rigid flexible rod connecting said two valve members for reciprocation together, and resilient means urging said first valve member to close both said channels and seat said exit valve member in such orifice.

13. In a nozzle having an exit orifice, a passage leading from the intake end of said nozzle to such orifice, an axially reciprocable regulating valve member adapted to open said passage under the influence of fluid intake pressure when such pressure exceeds a predetermined figure and to close said passage when such pressure drops below such figure, an axially reciprocable exit valve member adapted to close such orifice and aligned with said regulating valve member, longitudinally rigid but readily resiliently flexible wire means connecting said two valve members for reciprocation together but permitting a degree of misalignment therebetween, said flexible means being thus connected to said exit valve member in the near vicinity of such exit orifice, and resilient means urging said valve members to closed position.

14. In a nozzle having an exit orifice, a large and a small passage each leading from the intake end of such nozzle to such orifice, a regulating valve member reciprocably mounted to regulate admission of fluid to said large passage in response to fluid intake pressure thereagainst, an exit valve member aligned with said regulating valve member and reciprocably mounted to open and close such orifice, and longitudinally rigid but readily resiliently flexible means connecting said two valve members for reciprocation together while permitting a degree of misalignment therebetween, clearance being provided for slight lateral movement of said flexible means.

15. In a nozzle having an exit orifice, a passage leading from the intake end of said nozzle to such orifice, an axially reciprocable regulating valve member adapted to open said passage under the influence of fluid intake pressure when such pressure exceeds a predetermined figure and to close said passage when such pressure drops below such figure, an exit valve member axially reciprocably mounted to open and close such orifice, and longitudinally rigid flexible means connecting said two valve members for reciprocation together while permitting a degree of misalignment there-

between, clearance being provided for slight lateral movement of said flexible means.

16. In a nozzle having a fluid intake end and an exit orifice end, a small channel leading from such intake end to such orifice end and adapted to deliver a limited fluid flow thereto, an inner chamber axially disposed within said nozzle, said chamber being closed toward such orifice end of said nozzle, a regulating valve member axially reciprocable therein, a large channel leading from the side of said chamber to such orifice end and adapted to deliver a large fluid flow thereto when uncovered by said regulating valve member, an exit valve member adapted to close such orifice and carried by a stem axially reciprocably mounted in the closed end of said chamber, and means connecting said two valve members for reciprocation together, a vent to the outer atmosphere being provided for said chamber through said stem and exit valve member.

17. In a nozzle having an exit orifice, a passage leading from the intake end of said nozzle to such orifice, a regulating valve member axially reciprocable in a closed inner chamber within said nozzle and adapted to open said passage under influence of fluid intake pressure when such pressure exceeds a predetermined figure and to close said passage when such pressure drops below such figure, resilient means urging said regulating valve member to closed position, an exit valve member adapted to close such orifice and carried by an axially reciprocable stem, and means connecting said two valve members for reciprocation together, a vent for such chamber being provided through said stem and exit valve member.

18. In a nozzle having an exit orifice, and a passage leading from the intake end of such nozzle to such orifice; a regulating valve adapted to control fluid flow through such passage including a cylinder and a valve member mounted for reciprocation therein adapted to be urged to open position by fluid intake pressure, resilient means adapted to urge said valve member to closed position against the force of such intake pressure, a member extending from said cylinder axially through such orifice, and a venting passage in said latter member leading from the interior of said cylinder to the exterior of such nozzle.

19. In a closed orifice type nozzle having an exit valve member, a regulating valve adapted to control flow of fluid to such orifice comprising a piston mounted for reciprocation toward such orifice under influence of fluid intake pressure to uncover a port leading to such orifice, said piston and port being relatively contoured to permit fluid flow at a relatively low rate for initial substantial reciprocation of said piston and then an abruptly much increased flow upon slight additional reciprocation of said piston, resilient means adapted to urge said piston to valve closing position against the action of such intake pressure, and means connecting said piston and exit valve member for reciprocation in unison whereby said exit valve member is adapted initially to be rapidly moved to open position by such intake pressure but thereafter opened further at a reduced rate relative to the rate of increase of such pressure.

20. In a closed orifice type nozzle having an exit valve member, a regulating valve adapted to control flow of fluid to such orifice comprising a piston mounted for reciprocation toward such orifice under influence of fluid intake pressure to uncover a port leading to such orifice, said piston and port being relatively bevelled to permit fluid flow at a relatively low rate for initial substantial reciprocation of said piston and then an abruptly much increased flow upon slight additional reciprocation of said piston, resilient means adapted to urge said piston to valve closing position against the action of such intake pressure, means connecting said piston and exit valve member for reciprocation in unison whereby said exit valve member is adapted to be rapidly moved to open position by such intake pressure but thereafter opened further at a reduced rate relative to the rate of increase of such pressure and a separate independent and much smaller passage leading from the intake end of said nozzle to such exit orifice and having inconsequential capacity for fluid flow relative to that afforded by such port when the latter has been widely opened.

21. In a nozzle having an intake end and an exit orifice, a large and a small passage each leading from the intake end to such orifice, a regulating valve member mounted for reciprocation operative to open said large passage in response to increase in fluid intake pressure, resilient means operative to urge said member toward valve closing position, an externally seated outwardly opening exit valve member for such orifice, and means interconnecting said two valve members for reciprocation together.

22. In a nozzle having an intake end and an exit orifice, a large and a small passage each leading from the intake end to such orifice, a slide valve member mounted for reciprocation operative to open said large passage in response to increase in fluid intake pressure, resilient means operative to urge said member toward valve closing position, a poppet valve member adapted when reciprocated to open and close such orifice, and means interconnecting said two valve members for reciprocation together, with reciprocation of said slide valve member during initial opening movement of said poppet valve being insufficient to open said large passage.

23. In a nozzle having an intake end and an exit orifice end, an outwardly opening poppet valve member for such orifice having a stem mounted for reciprocation axially within said nozzle, a large and a small passage each leading from such intake end to such orifice, a slide valve member mounted for reciprocation axially in said nozzle to open and close said large passage in response to fluctuation of fluid intake pressure, resilient means operative to urge said slide valve member in a direction away from such orifice to close said large passage, longitudinally rigid means connecting said two valve members for reciprocation together, whereby action of said resilient means is also operative to urge said poppet valve member to closed position, and adjusting means for said connecting means adapted selectively variably to space said two valve members for desired sequence of opening of said large passage and exit orifice upon such conjoint reciprocation of said valve members.

24. In a nozzle having an intake end and an exit orifice end, a valve member mounted for axial reciprocation to open and close such orifice, and an inner valve member mounted for axial reciprocation adapted to regulate fluid flow within said nozzle; means interconnecting said respective valve members for mutually responsive reciprocation, and adjusting means for said connecting means adapted to vary the relative axial positions of said valve members to modify the valve opening and closing action thereof relative to each other.

25. In a nozzle having an intake end and an exit orifice end, an outwardly opening poppet valve member for such orifice having a stem mounted for reciprocation axially within said nozzle, a large and a small passage each leading from such intake end to such orifice, a slide valve member mounted for reciprocation axially in said nozzle to open and close said large passage in response to fluctuation of fluid intake pressure, resilient means operative to urge said slide valve member in a direction away from such orifice to close said large passage, a swirl chamber within said nozzle immediately upstream of such exit orifice, said large passage communicating therewith through a short transverse passage tangential to said swirl chamber and said small passage communicating therewith through a small helical passage entering said swirl chamber in a region radially inwardly of said tangential passage, and longitudinally rigid means connecting said two valve members for reciprocation together whereby action of said resilient means is also operative to urge said poppet valve member to closed position.

JOHN F. CAMPBELL.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,737,155	Hewitt	Nov. 26, 1929
1,833,080	Kenworthy	Nov. 24, 1931
2,408,680	Pontius	Oct. 1, 1946
2,434,151	Fisk	Jan. 6, 1948
2,439,832	Voit	Apr. 20, 1948
2,498,482	Cadman et al.	Feb. 21, 1950

FOREIGN PATENTS

Number	Country	Date
499,937	Germany	June 14, 1930
579,417	Great Britain	Aug. 2, 1946
837,789	France	Nov. 18, 1938