

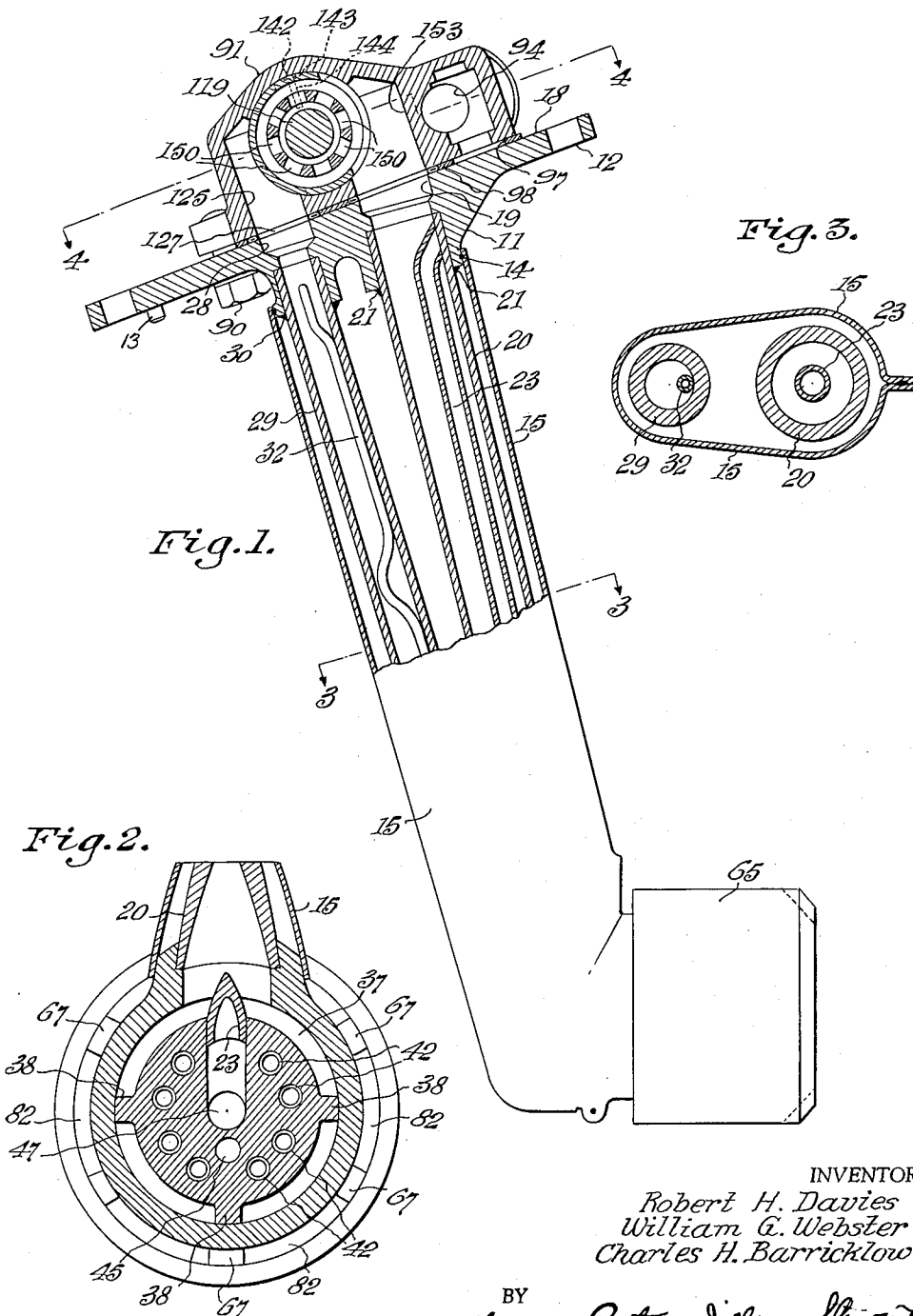
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R. H. DAVIES ET AL
LIQUID FUEL SPRAY NOZZLE

3,028,102

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4 Sheets-Sheet 1



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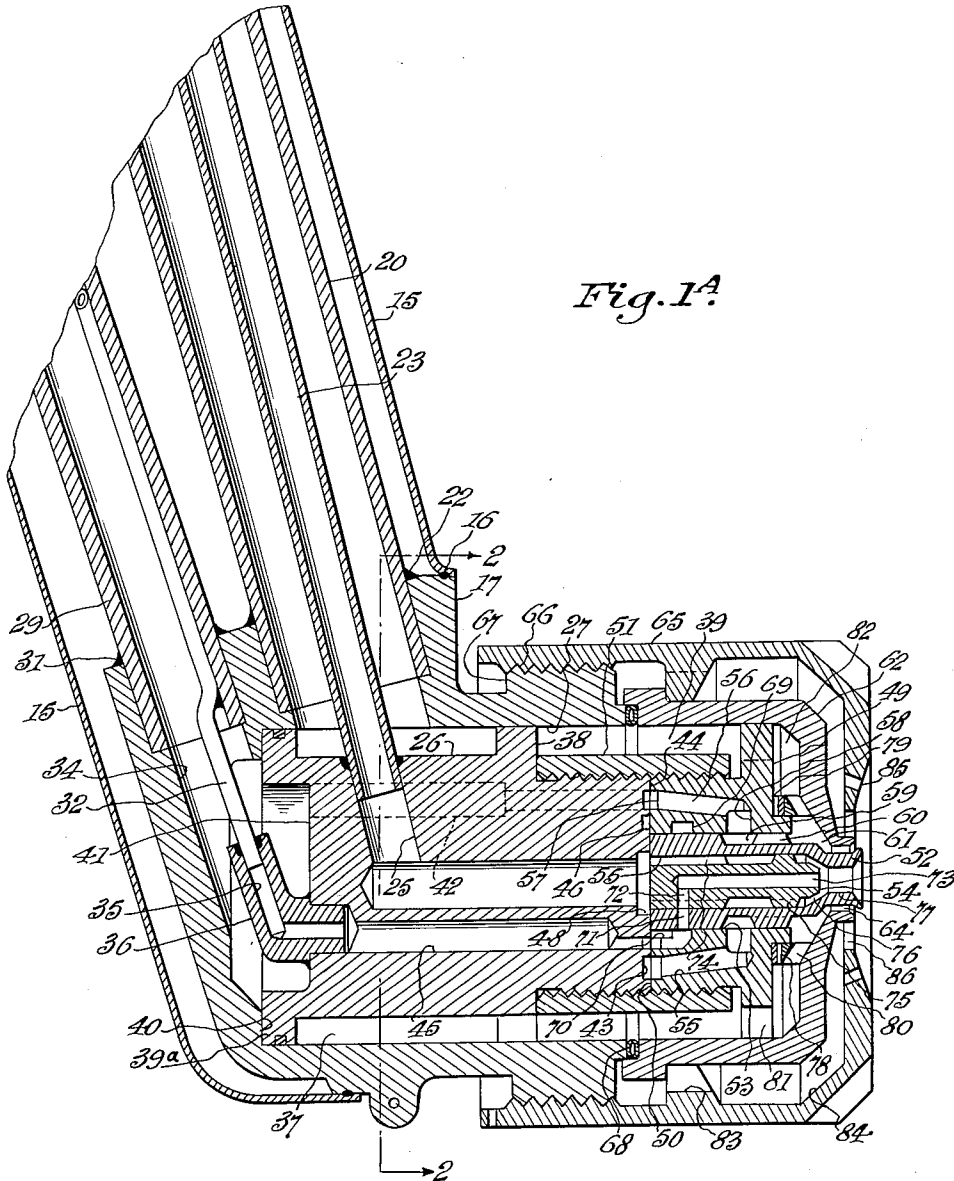
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4 Sheets-Sheet 3

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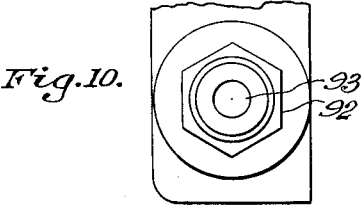
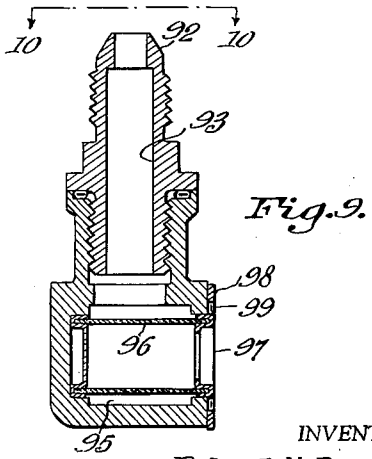
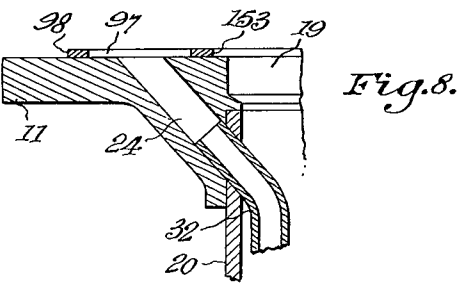
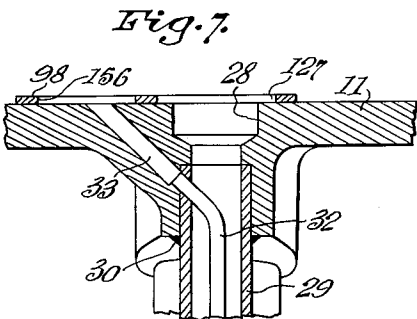
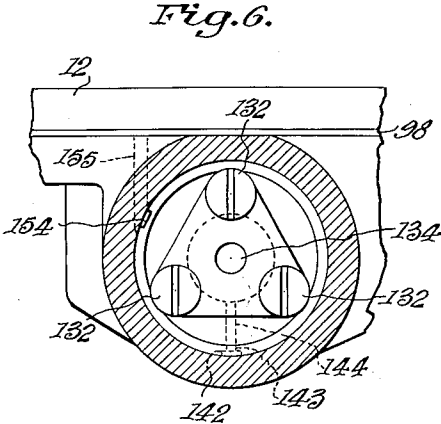
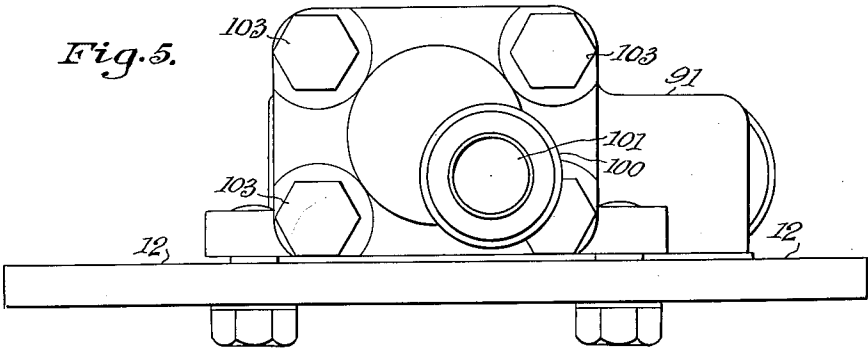
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LIQUID FUEL SPRAY NOZZLE

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5 Claims. (Cl. 239-404)

This invention relates to liquid fuel spray nozzles, and particularly to nozzles for use in spraying varying quantities of liquid fuel into combustion chambers of engines.

Present day requirements for aircraft engines call for a wide range fuel flow to be delivered to the engine, the range being as much as 125 to 1. A main problem in providing nozzles for such wide flow ranges is to obtain good atomization and spray pattern over all portions of the desired flow range.

One conventional method of obtaining atomization and a desired spray pattern is to provide nozzles with swirl slots and a spin chamber upstream of a discharge orifice. The swirl slots cause the liquid fuel to spin as it enters the spin chamber. The fuel then discharges from the spin chamber through the orifice, the latter causing the fuel to become atomized and to assume a spray pattern of conical configuration. The degree of atomization and the length and angle of the spray cone depends on several factors, such as velocity of the fuel through the orifice, the spin angle, the size and shape of the orifice, etc.

The velocity and spin angle at the orifice in turn depends upon such factors as supply pressure, size and shape of the spin chamber and swirl slots, etc. For simplicity and reliability it is desirable to fix the size and shape of the slots, chambers, and orifices.

When the size and shape of these elements are fixed, a wide variation in atomization and spray pattern normally results when fuel is passed through the nozzle over the wide range of flow rates required for aircraft engines. However, since the fluid pressure required to push the fuel through a nozzle having only one orifice, spin chamber, and set of swirl slots, increases as the square of the increase in total flow, it is not practical to use such a nozzle for widely varying flow rates because prohibitively high fluid pressures would be required for the higher end of the flow rate range. Also, considerable velocity is required at the orifice to obtain good atomization and flow pattern. This indicates small size slots, spin chamber and orifices for low flow rates and very high pressures for passing large quantities of fluid through such small slots, spin chambers, and orifices for high flow rates.

Various proposals have heretofore been made for obtaining good atomization and spray pattern over a wide range of flow rates without prohibitively high increase in the fluid supply pressure. One proposal is to provide a nozzle with two sets of swirl slots, spin chambers, and orifices, one set for providing good atomization and spray pattern at low flow rates and the other at high rates. In such instances, the set for low flow rates is relatively small in size so that the velocity at low flow rates is sufficient for obtaining good atomization and spray pattern. The other set is relatively large in size so that a greater quantity of fuel can be passed without an undue increase in the fuel supply pressure. The small set is constantly open to the fuel supply and provides all of the flow at the low flow rates. The large set is cut in by a regulating valve when the supply pressure has reached a predetermined value and adds to the flow through the small set to provide high total flow rates. This type sometimes referred to as a double cone nozzle.

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Since the two sets of slots, spin chambers, and orifices are independent of each other in a double cone nozzle, the high velocity of fuel developed in the small set does not aid in developing high velocity in the large set during that part of the total flow range when the regulating valve is sufficiently open to pass only a small quantity of fuel through the large set. Hence, there will be poor atomization and spray pattern of the fuel passing through the large set at this time, that is, for intermediate total flow rates.

To overcome this deficiency at intermediate flow rates in double cone nozzles, it has heretofore been proposed to utilize nozzles having sets of small and large swirl slots, both feeding a common spin chamber and orifice. In this arrangement, referred to as a duplex nozzle, the initial flow is through the small slots which impart a high velocity to the fuel as it passes into the common spin chamber and discharges from the common orifice. At some predetermined intermediate total flow rate (and hence, predetermined fluid pressure), a regulating valve opens to direct fluid from the supply line through the large slots and then to the common spin chamber and orifice. The initial flow through the large slots does not impart a high velocity to the fuel passing there-through, but such fuel mingles in the common spin chamber with the fuel discharged into the chamber at high velocity by the small slots. The resultant velocity is sufficiently high for obtaining good atomization and spray pattern as the mingled fuel discharges from the common orifice.

However, in order for duplex nozzles to handle relatively larger flow rates through the common spin chamber and orifice, these must be fairly large in size. As a result, good atomization and spray pattern are not obtained for the lower end of the flow rate range provided by the small swirl slots before the regulating valve opens, since some of the velocity imparted by the small slots is lost due to the relatively larger size of the common spin chamber and orifice.

To sum up, the double cone nozzle provides good characteristics at low and high total flows but is deficient at intermediate flows, while the duplex nozzle is good at intermediate and high total flows but deficient at low flows.

It is an object of the present invention to provide a nozzle which will have good atomization and spray pattern over all portions of a wide range of flow rates and without an undue increase in supply pressure from the low to the high rates. This is accomplished by combining the features of double cone and duplex nozzles. That is, by providing a small orifice with an associated small spin chamber and small swirl slots for good characteristics at low total flows, and by providing a large orifice and large spin chamber common to a separate set of small and large swirl slots for good characteristics at intermediate and high total flow rates.

Another object of the invention is to provide a novel and efficient arrangement for the regulating valve in the nozzle which opens at a predetermined fluid pressure to introduce fuel to a small set of swirl slots and which, at a somewhat higher supply pressure directs fuel to a set of large swirl slots, which arrangement facilitates manufacture, assembly, servicing, and functioning of such regulating valve.

Another object is to provide a novel and efficient arrangement of that portion of the nozzle containing the various swirl slots, spin chambers, and orifices for facilitating manufacture, assembly, servicing, and functioning thereof.

It is another object to provide a nozzle of the type described incorporating a novel means for venting the regulating valve to a relatively constant reference pressure for

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more accurately controlling the opening of the regulating valve by supply pressure.

Other objects will become apparent from the following description of the construction and operation, as well as from the drawings in which:

FIGURE 1 is a longitudinal cross-section view of the nozzle assembly taken on section line 1—1 of FIGURE 4 on a reduced scale.

FIGURE 1A is a vertical section of the lower portion of nozzle of FIGURE 1 on an enlarged scale.

FIGURE 2 is a cross-section view along lines 2—2 of FIGURE 1A on a reduced scale.

FIGURE 3 is a cross-section view along lines 3—3 of FIGURE 1.

FIGURE 4 is a cross-section view along lines 4—4 of FIGURE 1 on an enlarged scale.

FIGURE 5 is a fragmentary side view of FIGURE 4.

FIGURE 6 is a fragmentary section view along the lines 6—6 of FIGURE 4.

FIGURE 7 is a fragmentary section view along the lines 7—7 of FIGURE 4.

FIGURE 8 is a fragmentary section view along the lines 8—8 of FIGURE 4.

FIGURE 9 is a fragmentary section view along the lines 9—9 of FIGURE 4.

FIGURE 10 is a fragmentary end view of FIGURE 9 along the lines 10—10.

The nozzle assembly includes a plate 11 which is provided with a series of holes 12 by means of which the assembly may be mounted on the engine. A dowel pin 13 may be provided for accurate location on the engine.

The plate 11 is brazed as at 14 to a non-circular tube 15 and the latter is brazed as at 16 to a nozzle holder body 17. The upper face 18 of the plate 11 has a circular opening 19 which is in communication with the interior of a tube 20 which is brazed to the plate 11 as at 21 and which is brazed to the body 17 as at 22. A smaller diameter tube 23 is mounted inside the tube 20. One end of the tube 23 is pressed or brazed into an opening 24 in the plate 11, the opening 24 intersecting the upper face 18. The other end of the tube 23 is brazed into an opening 25 in a liner 26 which is mounted in a bore 27 of the holder body 17.

The plate 11 has an additional opening 28 leading from the face 18 and communicating with the interior of a tube 29 which is brazed to the plate 11 as at 30 and which is also brazed to the holder body 17 as at 31. A tube 32 is mounted within the tube 29, and at its upper end is brazed into an opening 33 of the plate 11 and at its other end passes through an opening 34 in the holder 17 and is brazed within an opening 35 of an elbow adapter 36 which in turn is brazed to the liner 26.

The liner 26 is spaced from the bore 27 of the holder 17 so as to provide an annular flow passage space 37 which is in open communication with the interior of the tube 20. A plurality of fingers 38 locate the outer end of the liner 26 within the bore 27 and the spaces between the fingers establish communication between the annular chamber 37 and an annular chamber 39 outwardly of the fingers 38.

The inner end of the liner 26 has a flange 39a which is seated against a shoulder 40 of the bottom of the body bore 27, and the flange 39a may be brazed or press fitted to the holder 17.

The inner end of the liner 26 has a recess 41. A series of drilled holes 42 connect the recess 41 to an annular groove 43 formed in the flat outer end face 44 of the liner. A hole 45 in the liner connects the passage 35 of the elbow adapter 36 to an annular groove 46 in the outer face 44 of the liner. Another hole 47 connects the opening 25 to a counterbore opening 48 in the end face 44.

A member 49 has a flat innerface 50 which is held in abutting engagement with the liner end face 44 by a nut 51 which has threaded engagement with both the liner 26 and the member 49. The member 49 includes an insert

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52 press fitted within a bore 53 of the member, and also a plug 54 which is press fitted within a bore 55 of the insert. The member 49 has a plurality of drilled holes 56 which connect an annular groove 57 in the member end face 50 in register with the annular groove 43 with an annular undercut 58 in the bore 53. The annular undercut 58 is opposite an annular groove 59 in the insert 52.

A series of helical slots 60 is formed on the insert 52 and connect the annular groove 59 with a swirl or spin chamber 61 formed between the insert 52, member 49, and another member 62. The member 62 includes a reduced diameter portion 63 which with an opposed wall of insert 52 provides an annular exit orifice 64. Preferably the outer face of the reduced diameter portion 63 is beveled and the outer portion of the insert 52 is flared out slightly so as to facilitate the forming of a conical spray pattern by fluid passing through the orifice.

The member 62 is clamped against the outer face of the body 17 by a shroud 65 having a threaded connection 66 with a series of lugs 67 formed on the holder body 17. The joint between the holder 17 and the member 62 is preferably sealed by a hollow metal O-ring 68.

The member 49 has an additional annular undercut 69 which communicates by means of a hole 70 with the annular groove 46 and which opens into a hole 71 which connects with drilled openings 72 and 73 in the plug 54.

The plug 54 has a series of longitudinal slots 74 which connect the opening 48 with a series of helical swirl slots 75 formed at the outer end of the plug 54 and leading to a swirl or spin chamber 76 and then to an orifice 77 formed in the outer end of the insert 52.

Another insert 78 is interposed between the member 49 and the member 62 and is held firmly against the latter by means of a wave washer 79. The insert 78 has a series of tangential slots 80 therein for imparting swirl to fluid passing therethrough and into the swirl or spin chamber 61. A series of slots 81 in the member 49 permits fluid to pass from the annular chamber 39 to a chamber 82 adjacent the swirl slots 80.

Spaces 82 between the threaded lugs 67 permit air to be drawn into the shroud 65 through slots 83 into the passageway 84 between the shroud and the member 62 and into the engine combustion chamber through the holes 85 and the opening 86.

Attached to the plate 11 by means of bolts 90 is a valve housing 91. This housing has an inlet fitting 92 for connection to a source of fluid supply. The interior 93 of this fitting communicates with a drilled opening 94 in the housing 91 which in turn connects and communicates with a filter chamber 95 in which a filter 96 is mounted. The interior of the filter 96 is open to a hole 97 in a spacer 98 interposed between the housing 91 and the plate 11. The opening 97 is sealed by a metal O-ring 99.

The opening 97 in the spacer 98 communicates with the opening 24 in the plate 11 and hence with the interior of the tube 23.

The housing 91 has another inlet fitting 100 for connection to a source of supply. This fitting has inlet passages 101 and 102 and it is connected to the housing 91 by means of bolts 103. The passage 102 is open to the interior of a conical screen 104 attached to a collar 105 and held in place between a wave washer 106 and a liner 107 closely fitting a bore 108 in the valve housing 91. Mounted in the liner 107 is a fine filter 109. Press fitted into the liner 107 is a sleeve 110. The sleeve 110 has a threaded opening 111 having a bottom wall 112. A valve sleeve 113 is secured in the threaded opening 111 by a hollow nut 114 and a hollow lock nut 115. A bore 116 through the sleeve 113 is in communication with the bore 117 of the cylindrical fine filter 109.

The upper end portion of the valve sleeve 113 forms a valve seat against which a seat face 118 of a valve poppet 119 may be seated. The upper end 120 of the valve sleeve 113 is spaced from a seat portion 121 on the

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sleeve 110 so as to provide an annular chamber 122 which is in communication with an annular groove 123 in the sleeve 110 by means of radial holes 124. The annular groove 123 is open to an opening 125 in the valve housing 91 through a slot 126 in the liner 107. The opening 125 is in register with an opening 127 in the spacer 98 which in turn registers with the opening 28 in the plate 11.

The valve poppet 119 has a second seat surface 128 spaced from the seat surface 118 and cooperating with the seat portion 121. The valve poppet is normally urged to a downward position with the seat 118, which is conical, inclosing contact with the end of the valve sleeve 113, and with the seat surface 128 overlapping the seat portion 121 for effecting a closure at both of these points. A spring 129 is utilized for urging the valve poppet toward closed position. One end of the spring 129 presses against a shim 130 which is interposed between the spring and the interior of the valve poppet 119, and the other end abuts a plate 131 bolted to the liner 110 by three screws 132. An opening 134 in the plate 131 vents the interior of the poppet and of the bore 135 of the sleeve 110 in which the valve poppet slides.

The valve housing is closed by a cap 136 which has a recess 137 in communication with the opening 134 and also with a chamber 138 formed between the cap 136 and the valve housing 91.

The liner 107 has a radial opening (not shown) opposite the filter 109 which connects the interior or bore 141 of the liner with a longitudinal slot 142 formed in the outer face of the liner 107 and extending to another radial opening 143 near the upper end of the liner 107. The radial opening 143 is in register with another radial opening 144 in the sleeve 110 which in turn leads to an annular groove 145 in the sleeve 110. There is another annular groove 146 in the sleeve 110.

Downstream of the valve seat 121 are a series of radial openings 150 leading to an annular groove 151 in the sleeve 110. This groove registers with an opening 152 in the liner 107 and the latter communicates with an opening 153 in the spacer 98 and the opening 153 in the plate 11.

A slot 154 in the outer surface of the liner 107 connects the chamber 138 with a drilled opening 155 in the valve housing 91 and this drilled opening in turn communicates with a hole 156 in the spacer 98 and then with the opening 33.

In operation, the nozzle is mounted by means of plate 12 to the engine with the lower end of the nozzle projecting into the combustion chamber. Suitable fuel supply lines are connected to the inlet fittings 92 and 100. When the fuel supply is turned on by some means in the fuel supply system not shown in the accompanying drawings, the liquid fuel will enter the fitting 92 and pass through the openings 94, 95, and 24 into the tube 23. From the latter it will pass through the openings 25, 47, and 74 to the helical swirl slots 75 into the spin chamber 76 and be atomized and formed into a conical spray pattern as it discharges into the combustion chamber through the orifice 77.

Fuel from the supply line will also enter fitting 100 and pass into the interior of the valve housing 91. But as long as the pressure of the incoming fuel is less than a predetermined amount, the spring 129 will keep the valve poppet 119 in closed position to prevent passage of fuel through the valve housing 91, except for a small flow which will be described later.

When the pressure of the fuel entering the fitting 100 reaches a predetermined value, the pressure of the fuel on the lower end of the valve poppet 119 will move the latter upwards against the action of the spring 129. The initial opening movement will unseat a portion 118 of the valve poppet from its positive engagement with the valve seat provided by the end of the sleeve 113

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and permit flow of fuel from the interior of the sleeve 113 pass the valve seat portion 118 into the annular space 122 from which it passes through the radial openings 124, the annular groove 123, openings 125 and 28 into the interior of the tube 29. From the latter it passes into the recess 41 and then through the openings 42, 43, 56, 58, and 59 to the swirl slots 60. The latter impart a swirling motion to the fuel as it enters the spin or swirl chamber 61 and is then atomized as it is discharged through the orifice 64 in conical spray pattern form into the combustion chamber.

Further increase in pressure of the fuel entering the fitting 100 will cause the valve poppet 119 to open further against the spring 129 to disengage the seat portion 128 of the valve poppet from its sliding fit with the seat portion 121 and permit flow of fuel from the interior of the sleeve 113 into the openings 150, 153, and 19 into the tube 20. From the latter the fuel flows into the annular chambers 26 and 39 into the chamber 82 from which it is delivered to the swirl slots 80. The latter impart a spin or swirl to the fluid as it enters the spin chamber 61 to mingle with fuel delivered through the spin slots 60 and is combined therewith to be atomized and discharged into the combustion chamber through the orifice 64.

It will be noted that the flow passages downstream of the valve seat 121 and leading into the swirl slots 80 are of substantially greater capacity than the previously described passages leading to swirl slots 75 and 60. Likewise, the flow capacity of swirl slots 80 is substantially greater than the flow capacity of either of the swirl slots 75 or 60. Likewise, orifice 64 is of greater capacity than orifice 77 and spin or swirl chamber 61 is of greater capacity than spin or swirl chamber 76. By reason of this arrangement, a relatively small amount of flow will pass into fitting 92 and the associated ducts leading to the swirl slots 75 and be discharged by the latter at high velocity into the small spin or swirl chamber 76 and the small orifice 77 even though the supply pressure at fitting 92 is relatively low.

When the inlet or supply pressure has been increased to a predetermined value, the flow continues through the fitting 92 and its associated passageways, but an additional flow path is opened by the valve seat portion 118 to supply additional fuel at a relatively low rate of flow to the small swirl slots 60 from where it is discharged at high velocity into the spin or swirl chamber 61 and out through the orifice 64.

As the supply pressure increases to a second predetermined value, the valve seat portion 128 opens the relatively large passageways leading to the large spin slots 80 which delivers the swirling fluid at high velocity to the spin or swirl chamber 61. By this means, good atomization and spray pattern is maintained from the initial flow rate when fuel is supplied only through the fitting 92, through intermediate and high flow rates.

To assure free operation of the poppet valve 119, a means is provided for continuously introducing finely filtered fuel in the sliding fit between the bore 135 and the valve skirt 160 and thus prevent any contaminant which might be in the unfiltered fuel from working its way into the sliding fit and causing the valve to stick. To accomplish this, some of the fuel which enters the inlet fitting 100 passes through the screen 104 and through the fine filter 109 into the annular space 161 between the filter and the liner 107. The filtered fuel then passes through a radial opening in the liner 107 opposite the filter 109 into a longitudinal slot 142 on the outside surface on the liner 107 and extending to a point opposite the undercut 145 in the sleeve 110. At this point, the slot 142 connects with a radial opening 143 in the liner 107 which in turn registers with a radial opening 144 in the sleeve 110 leading to the groove 145. The finely filtered fuel from the undercut 145 works its way into the sliding fit between the valve skirt 160 and the bore 135 in both

directions from the groove 145. Seepage of this fluid in the upper direction discharges through the spring 129 into the interior of the poppet valve 119 from which it may be vented to the combustion chamber, as will be described.

Seepage of filtered fluid from the groove 145 downwardly in the sliding fit between the poppet valve and the bore 135 collects in the annular undercut 146 and then passes into the opening 150 and then to the opening 153, from which it makes its way through the tube 20, annular chambers 26 and 65, swirl slots 80 and out through the orifice 64.

To prevent hydraulic locking of the poppet valve 119 in the closed position, and also to subject the rear faces of the poppet valve 119 to a substantially constant reference pressure and thus facilitate accurate opening and closing response of the poppet valve in accordance with the pressures existing in the sleeve 118 against the lower side of the poppet valve, a means is provided for venting the fluid which collects on the rear side of the poppet valve. This vent passage comprises the opening 134, recess 137, space 138, slot 154 in the outer face of the liner 107, opening 155 in the valve housing 91, opening 156 in the spacer 98, opening 33, tube 32, openings 35, 45, 70, 71, 72, and 73. Opening 73 is exposed to the pressure existing in the combustion chamber since the spinning fuel passing through the orifice 77 from the spin or swirl chamber 76 hugs the wall of the orifice 77 to leave the central portion of the orifice 77 in direct communication with the interior of the combustion chamber.

I claim:

1. A fuel nozzle having first and second discharge orifices, a first fluid intake passage adapted to be connected to a controlled source of fuel under pressure and leading to first spin elements and then to said first discharge orifice for supplying an initial low pressure fuel charge, a second fluid intake passage, said second fluid intake passage including a main portion and a pressure responsive valve controlled continuation portion branching from said main portion and leading to second spin elements and then to said second discharge orifice for supplying an additional quantity of fuel as the pressure of the fuel increases, a third passage branching from said second fluid intake passage main portion sequentially controlled by said pressure responsive valve and leading to third spin elements and then to said second orifice for increasing the quantity of fuel delivered in response to a further increase in fuel pres-

sure, said pressure responsive valve maintaining said second fluid intake passage continuation portion and said third passage closed under low fuel pressure conditions and sequentially opening first the continuation portion to a fully opened position and then the third branching passage in response to increases in fuel pressure whereby the quantity of fuel passing through each of said spin chambers is controlled responsive to fuel pressure.

2. The fuel nozzle of claim 1 wherein said pressure responsive valve includes said second fluid intake passage main portion having first and second ports opening into said continuation portion and said third passage, respectively, a first valve seat extending around said main portion upstream of said first port, a second valve seat upstream of said second port, a valve member within said main portion for movement axially of said main portion by direct fluid pressure thereon within said main portion to first fully uncover said first port and then uncover said second port.

3. A fuel nozzle in accordance with claim 2 wherein said valve member has a first portion for seating directly against said first valve seat in opposed relation to fluid in said main portion and a second portion passing through and having a sliding fit with said second valve seat for closing the same.

4. A nozzle in accordance with claim 1 in which said first and third passages are of substantially smaller flow capacity than said second passage.

5. The fuel nozzle of claim 1 wherein said second fluid intake passage continuation portion opens into a spin chamber intermediate said second spin elements and said discharge orifice, and said third branching passage opens into said spin chamber intermediate said third spin elements and said second discharge orifice.

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