Oct. 14, 1952 T C. NOON ET AL 2,613,998

VARIABLE AREA FUEL NOZZLE

Filed Sept. 15, 1948 2 SHEETS—SHEET 1

Fig. 3

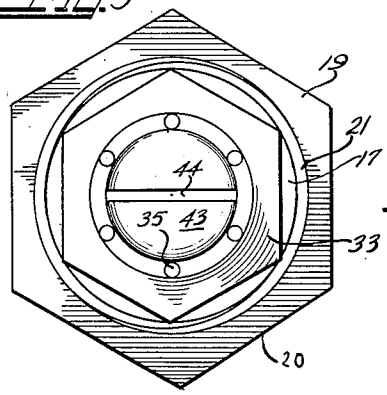


Fig. 4

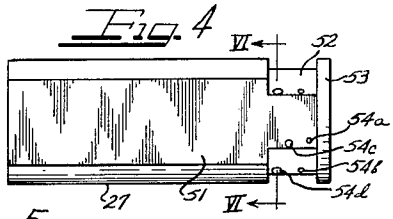


Fig. 5

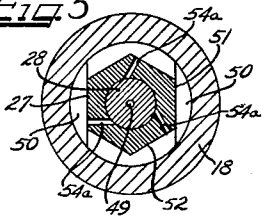


Fig. 6

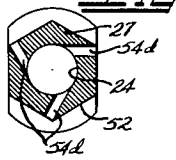


Fig. 1

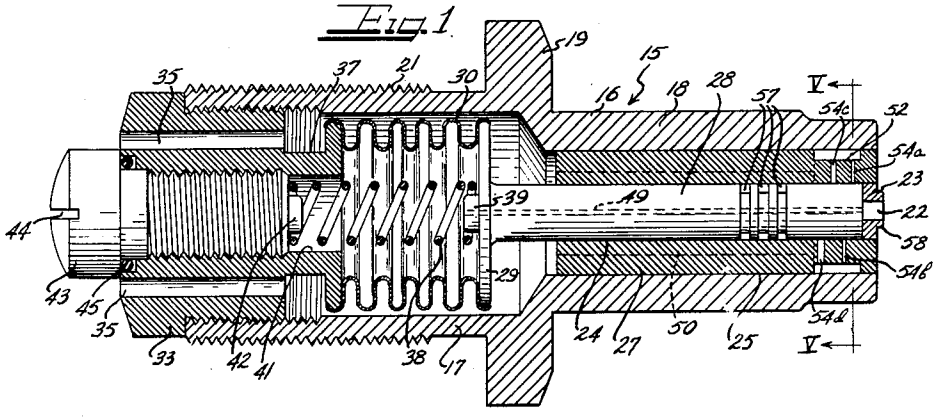
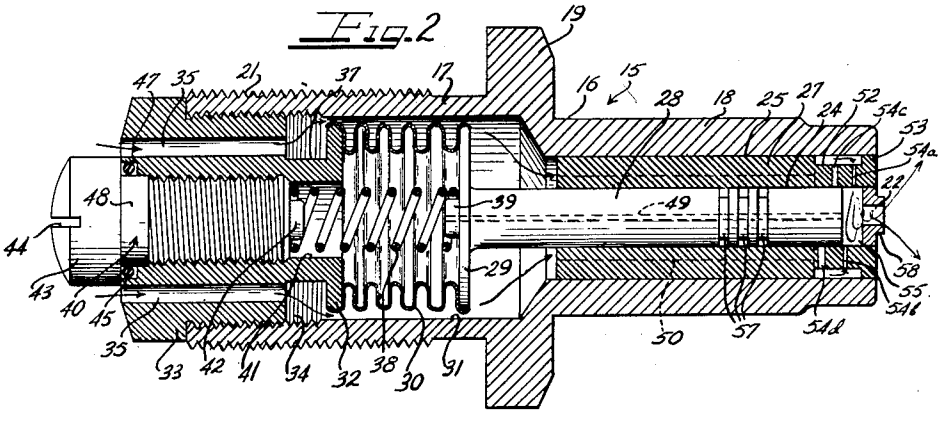


Fig. 2



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VARIABLE AREA FUEL NOZZLE

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Fig. 7

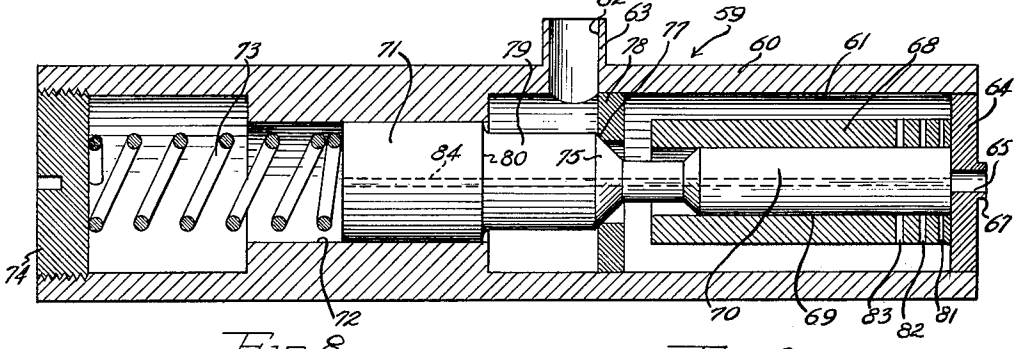


Fig. 8

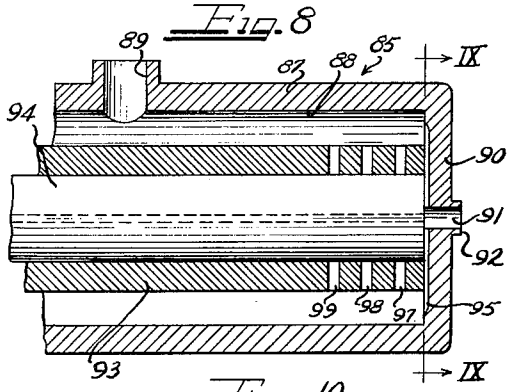


Fig. 9

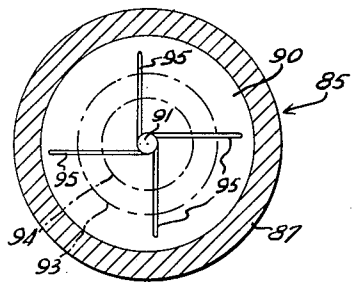


Fig. 10

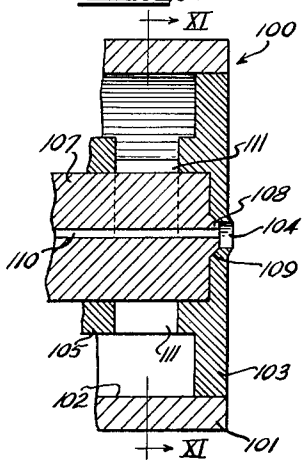
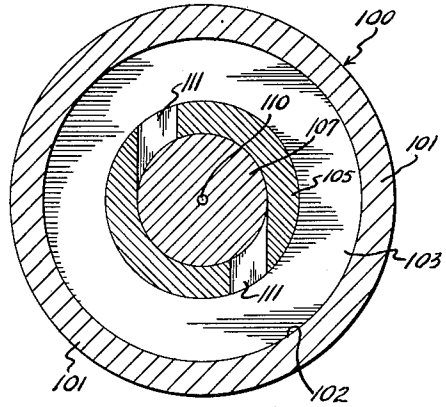


Fig. 11



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UNITED STATES PATENT OFFICE

2,613,998

VARIABLE AREA FUEL NOZZLE

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Application September 15, 1948, Serial No. 49,414

1 Claim. (Cl. 299—133)

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The present invention relates to improvements in fuel nozzles and more particularly concerns variable area fuel nozzles of a type adapted for use in supplying a finely atomized spray of fuel to the burners of a gas turbine or jet engine such as may be used in aircraft.

Substantially uniformly fine atomization of the fuel supplied to the burners of a gas turbine or jet engine is highly important. The quality of atomization must not be less during periods of low fuel demand than in periods of high fuel demand. That is, during low fuel demand pressure in the fuel supply line is generally relatively low so that in the absence of some provision to enhance the orifice pressure at the fuel nozzle inadequate atomization may result. On the other hand, in the absence of some means to effect adaptation at the fuel nozzle to increased supply line pressure as the fuel demand increases, the character of the spray emitted by the nozzle may be adversely conditioned.

The present invention provides improved expedients for economically and efficiently accommodating the entire range of conditions which are encountered in the supply of finely atomized spray of fuel to the burners of a gas turbine or jet engine and which arise primarily due to variations in fuel demand or pressure and the consequent variation in the fuel supply volume.

An important object of the present invention is to provide for supplying finely atomized fuel in a spray having a substantially constant quality throughout a wide range of fuel supply pressure and volume.

Another object of the invention is to provide an improved fuel atomizing nozzle of variable area and which is automatically adjustable as to area proportionate to the fuel supply pressure.

A further object of the invention is to provide a new and improved variable area fuel nozzle structure of simple and economical construction and highly efficient operation.

Still another object of the invention is to provide in a variable area fuel nozzle improved means to assure smooth and uniform operation.

Yet another object of the invention is to provide in an atomizing fuel nozzle improved means to assure that the spray will break clean from the discharge orifice.

Other objects, features and advantages of the present invention will be readily apparent from the following detailed description of certain preferred embodiments thereof taken in conjunction with the accompanying two sheets of drawings, in which:

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Figure 1 is a longitudinal sectional view through a variable area fuel nozzle construction embodying features of the invention;

Figure 2 is a longitudinal sectional view of the same fuel nozzle as shown in Figure 1 but with the relatively movable parts in the condition assumed during operation;

Figure 3 is an end elevational view of the fuel nozzle of Figure 1 looking toward the left or rear end of the nozzle as shown;

Figure 4 is a side elevational view of the port insert member of the fuel nozzle;

Figure 5 is a transverse sectional view taken substantially on the line V—V of Figure 1;

Figure 6 is a transverse sectional view taken substantially on the line VI—VI of Figure 4;

Figure 7 is a longitudinal sectional view of a modified form of the variable area fuel nozzle;

Figure 8 is a fragmentary longitudinal sectional view through a further modified form of the fuel nozzle;

Figure 9 is a transverse sectional view taken substantially on the line IX—IX of Figure 8;

Figure 10 is a fragmentary longitudinal sectional view through a still further modified form of the fuel nozzle; and

Figure 11 is a transverse sectional detail view taken substantially on the line XI—XI of Figure 10.

In producing a finely atomized spray having a definite shape when introducing fluid fuel to the burners of a gas turbine or jet engine or the like, according to the present invention, the fluid fuel is forced under pressure from a fixed orifice of predetermined aperture side and length, and immediately before the fluid enters the orifice a strong swirling motion is induced therein. As a result a hollow and conically shaped spray pattern is created rather than merely a jet. This is accomplished by having the fluid enter tangentially into a cylindrical swirl chamber immediately upstream from the orifice so that the fluid is in rapid rotary motion as a vortex about the axis of the orifice where it enters the orifice and accelerates due to the constriction afforded by the orifice, leaving the orifice with a violent, expanding spiral motion which insures the desired hollow conical shape in the spray pattern and thorough atomization of the fluid.

In order to maintain the atomization quality of the hollow, conical spray pattern substantially constant throughout a large variable range of fuel demand, the area of the swirl chamber is varied in substantially direct ratio to the fuel demand or pressure. To this end, the area of the swirl

chamber is increased in proportion to the pressure of the fuel supplied to the orifice, and at the same time the volume of fluid supplied to the swirl chamber is increased. As a result the swirl rate, that is, the speed with which the fluid rotates in the swirl chamber remains substantially the same throughout the variable fluid supply pressure range, and while the amount of fluid emitted from the spray orifice will vary accordingly and thus provide a lean or rich fuel mixture as required, the hollow, conical spray pattern will persist throughout the variable range.

In a preferred form of variable area nozzle for practicing the present invention and as shown in Figures 1 to 6, inclusive, a nozzle assembly **15** includes a housing or body **16** of elongated preferably generally cylindrical form including a larger diameter rear portion **17**, a smaller diameter forward end portion **18** and an intermediate lateral flange **19** which is preferably formed with a series of peripheral wrench faces **20** (Figure 3). Through this arrangement, the nozzle assembly is adapted to be mounted in the wall of a burner or in the wall of a fuel supply mechanism housing with the rear portion **17** secured in place through the medium of external threads **21** thereon by which it is adapted to be threaded into an appropriate aperture or cavity in the supporting wall. The flange **19** may be driven against the supporting wall in the fully tightened relationship of the body **16** when mounted, and the wrench faces **20** facilitate the tightening operation through the medium of a suitable wrench. In this mounted condition of the unit **15**, the forward nozzle portion **18** extends as a nose to a substantial extent into the burner chamber or through a port in the wall of such chamber, depending upon the particular construction and arrangement of the burner.

Fluid fuel is introduced through the rear end of the nozzle housing **16** and discharged through the forward end, the discharged fluid being emitted from an orifice **22** coaxial with the housing **16** and of a preferred predetermined diameter and length. In the present instance the orifice is formed in a plate or plug **23** which is fitted in the outer end of and sealingly closes such end of a cylindrical bore **24** of larger diameter than the orifice **22** but of smaller diameter than a cylindrical bore **25** in the body nose portion **18** and which accommodates in snugly press-fitted relation an insert sleeve or port member **27** within which the coaxial bore **24** is formed. The sleeve insert **27** is preferably approximately as long as the nose portion **18** and the bore **24** extends the full length of the sleeve.

Normally completely filling the sleeve bore **24** and bearing endwise in fluid sealing relation against the inner face of the orifice insert **23** about the orifice **22** is a fluid control plunger or piston **28** which is reciprocably slidable in the bore **24**. At its rear end, the piston **28** is preferably formed with an enlarged radial concentric flange **29** about the rim of which is sealingly secured an end of a Sylphon bellows **30**. The flanged rear end **29** of the plunger and the Sylphon bellows **30** are accommodated freely and with substantial peripheral clearance within an enlarged bore **31** within the rear portion **17** of the nozzle housing or body **16** and which merges at its forward end with the smaller diameter bore **25** in the nose portion **18**. At its rear end the Sylphon bellows **30** is secured in sealing relation to an annular radial flange **32** at the inner end of a closure plug **33** which is preferably threadedy secured into the

rear extremity of the rear tubular portion **17** of the nozzle body, the latter being internally threaded as at **34** for this purpose.

An annular series of longitudinally extending fluid bores **35** extending through the plug **33** (Figures 1, 2 and 3) open into an annular radially outwardly opening groove **37** in the inner end portion of the plug immediately behind the bellows attachment flange **32** and which provides a fluid entry clearance into the chamber afforded by the enlarged rear bore **31** of the nozzle housing. Through this arrangement, fluid pressure developing in the chamber within the bore **31** is adapted to act upon the exposed shoulder afforded by the inner or base flange **29** of the piston to compress the bellows **30** and force the piston **28** rearwardly, whereby to open a forward end portion of the sleeve bore **24** forwardly of the piston and behind the orifice insert **23**.

Predetermined resistance to the action of the fluid pressure tending to drive the piston **28** rearwardly is afforded by biasing means such as a helical compression spring **38** of substantially smaller diameter than the internal diameter of the bellows **30** and bearing at its forward end against the rear face of the piston flange **29** about a coaxial spring centering boss **39**. At its rear end, the spring is seated against the inner or forward end of a spring tension adjusting screw **40** which is threaded into a coaxial **41** in the plug **33** and has a coaxial spring centering boss tip **42**. The bore **41** is preferably of somewhat larger diameter than the spring **38** so as to clear the same for free compression and expansion action in operation.

By tightening or loosening the screw **40**, adjustment in the compression of the spring **38** may be effected, and thus the fluid pressure necessary to unseat the plunger or piston **28** from the orifice member **23** appropriately adjusted for optimum results in operation of the nozzle. For convenience in effecting adjustment of the screw **40**, it is provided with a head **43** accessible at the rear of the plug **33** and formed with means such as a screwdriver slot **44** to facilitate adjustment manipulation thereof. The diameter of the head **43** is preferably smaller than the diameter of the circle described by the fluid passage bores **35** so as to maintain the mouths of the latter clear.

Fluid leakage past the adjustment screw **40** is avoided by fluid sealing means such as appropriate O-ring sealing gasket means **45** accommodated within a rabbet groove **47** at the rear end of the plug bore **41** and in sealing engagement between the wall of the groove **47** and a cylindrical collar **48** on the screw **40** intermediate the head **43** and the threaded shank of the screw.

Pressure relief for the chamber within the bellows **30** is afforded by a small diameter vent or a relief bore **49** which extends coaxially through the piston **28** to afford communication between the ends of the piston and thereby between the bellows chamber and the orifice **22**. In this way, the piston **28** is adapted to move freely reciprocably, the spring **38** affording spring bias, in conjunction with whatever inherent spring bias may exist in the bellows **30**, tending normally to drive the piston into orifice blocking relation (Fig. 1), and the pressure of the fluid in the chamber afforded by the bore **31** tending to overcome the spring bias and drive the piston to orifice unsealing or opening position (Fig. 2). The piston assumes an operative position as determined by any particular balanced condition that may be

attained between the fluid pressure and the spring bias.

From the chamber 31, fluid passes forwardly through the nozzle housing nose portion 18 by way of a pair of longitudinal fluid passages 50 (Figures 1, 2 and 5) afforded by longitudinally flatted opposite parallel side portions 51 on the sleeve 27 and the opposing wall of the bore 25. At their forward ends, the fluid passages 50 communicate with an annular distribution groove 52 in the periphery of the sleeve 27, the forward or outer wall of the groove being defined by a closure head flange 53 on the sleeve (Figures 1, 2 and 4).

Communication between the distribution channel or groove 52 and the sleeve bore 24 is afforded by a plurality of ports 54*a*, 54*b*, 54*c*, and 54*d*, which are directed from the distribution channel 52 inwardly tangential to the wall of the sleeve bore 24. By preference, the several ports are provided in a series of annularly disposed axially spaced groups to become progressively uncovered as the piston 28 is moved rearwardly by fluid pressure in the nozzle. Furthermore, in order to accommodate an increasing volume of fluid substantially in proportion to the increase in pressure, the successive series or groups of ports are preferably of progressively increasing diameter and thus of increasing flow area. To this end, each of the groups of ports may be of equal number, such as three as shown in Figures 5 and 6, for example, the ports 54*a* being of the smallest diameter and thus of the lowest total cross-sectional flow area, and located adjacent to the forward side of the distribution groove 52 and spaced a relatively short distance rearwardly from the inner face of the orifice insert 23. The sets of ports 54*b*, 54*c*, and 54*d* are of progressively larger diameter and thus total cross-sectional flow area in the order named and are located in appropriately spaced relation, one group to the other in the order named front to rearwardly of the first group of ports 54*a*. In each group the ports are circumferentially equidistantly located. Furthermore, each of the groups of ports is preferably staggered with respect to at least the adjacent group or groups of ports, and their spacing is such that fluid entering therethrough into the sleeve bore 24 provides generally overlapping streams with the streams of the adjacent groups of ports, considered longitudinally of the sleeve bore.

In operation, until the fluid pressure in the nozzle assembly 15 and more particularly within the chamber 31 attains a value sufficient to overcome the spring bias on the piston 28 to move the piston enough to uncover the first set or group of tangential ports 54*a*, the nozzle remains shut off by the sealing relation of the forward tip of the piston 28 against the orifice insert 23, whereby the orifice 22 is closed against fluid discharge and atomization. When the piston has been moved by the automatic action of the fluid pressure to uncover the first set of ports 54*a*, the pressure forces the fluid from the distribution channel 52 through the ports 54*a* and into the area forwardly of the forward tip of the piston 28 and behind the orifice insert 23 serving as a swirl chamber 55 (Figure 2). In the swirl chamber, the fluid entering tangentially under the substantial force of the main body of the fluid, and after developing substantial velocity in passing through the relatively small first ports 54*a*, whirls around at high velocity in a spiral, vortex path to the entrance to the orifice 22 into which it

passes as a tubular column with substantially undiminished or increasing whirling velocity and under pressure resulting from the orifice restriction. From the mouth of the orifice 22 the fluid, spinning at high velocity, is projected as a finely atomized hollow cone-shaped spray stream.

As the fluid pressure increases the plunger or piston 28 is moved successively further rearwardly and successively uncovers the sets of ports 54*b*, 54*c*, and 54*d* depending, of course, upon the fluid pressure and remaining at any intermediate open position should the fluid pressure and the spring bias attain a substantially balanced relationship. As the swirl chamber 55 enlarges in area in the progressive pressure induced retreat of the piston 28, increased volume of fluid enters the chamber in proper proportion to maintain substantially constant fluid velocity at the orifice 22. This assures that the atomization quality of the spray stream from the nozzle will remain substantially constant even though the volume of fluid emitted in the spray stream may vary from time to time throughout the entire variable area range afforded by the several sets of ports and the variable area swirl chamber 55.

Fluid sealing and dirt catching means may be provided in the form of a series of parallel annular grooves 57 in the periphery of the plunger or piston 28 spaced from the forward tip thereof.

In order to insure that the spray stream from the orifice 22 will break clean and not tend to run along the face of the orifice member 23 due to adhesion, a lip or extension 58 is provided to project forwardly from the orifice insert 23 about the mouth of the orifice 22. This lip or extension 58 forces the fluid to break away from the surface of the orifice member and form a more distinct spray cone.

In the modification of Figure 7, a nozzle assembly 59 is shown including an elongated hollow body or casing member 60 within the forward portion of which is a relatively large diameter bore 61 providing a fluid chamber into which leads an inlet port 62 from one side of the casing or housing and defined by an inlet boss 63. At its forward end, the chamber 61 is closed by an orifice plate 64 having an axial orifice 65 defined by a protruding lip 67.

The chamber 61 is of larger diameter than a sleeve member 68 which is mounted on the inner face of the orifice plate 64 and has a bore 69 concentrically related to the orifice 65 and of larger diameter. Within the bore 69 is a plunger 70, the forward end of which is normally adapted to bear against the inner face of the orifice plate 64 in sealing relation to the orifice 65. At its rear end, the plunger 70 is provided with an enlarged diameter portion 71 which is slidably guided as a piston in a reduced diameter section 72 of the housing bore. Biasing means, such as a coiled compression spring 73 bears against the rear end of the piston portion 71 and is in engagement at its other end with a closure plug 74 which closes the rear end of the body bore. The plug 74 is adjustably threaded into the body bore so as to adjust the tension of the spring 73.

In its orifice sealing position under the influence of the biasing spring 73, the plunger 70 has an intermediate generally frusto-conical, poppet valve portion 75 sealingly seated against a valve seat 77 provided by a ported barrier plate 78 disposed intermediate the inlet 62 and the rear end of the plunger guide sleeve 68. Rear-

wardly of the valve portion 75 the plunger has a cylindrical portion of intermediate diameter identified at 79 and which merges with the cylindrical piston portion 71 on an annular forwardly facing shoulder 80.

In operation of the form of Figure 7, fluid entering through the inlet 62 is trapped in the chamber between the barrier wall 78 and the opposing shoulder at the mouth of the reduced diameter bore portion 72 and the piston shoulder 80. When the pressure of the fluid is greater than the pressure exerted by the biasing spring 73, the piston portion 71 is moved rearwardly and thus causes the valve portion 75 to leave the valve seat 77 whereby to crack the valve and at the same time the plunger 70 moves away from the entrance to the orifice 65. The fluid escaping past the valve seat 77 into the bore chamber 61 is delivered by way of radial or tangential ports 81 of relatively small diameter and thus small aggregate cross-sectional flow area adjacent to the forward end of the sleeve 68 into the forward swirl chamber portion of the sleeve bore 69 where, similarly as in the swirl chamber 55 (Figures 1 and 2), the fluid swirls with sufficient acceleration to travel in a vortex flow to exit through the orifice 65 from which it is emitted as a hollow cone-shaped atomized spray stream. Greater pressure of the fluid entering the nozzle assembly further unseats the plunger 70 until a series of ports 82 of larger diameter is uncovered to afford increased fluid volume in the increased area of the swirl chamber. Still further opening movement of the plunger 70 uncovers a series of ports 83 disposed successively after the ports 82 and of larger individual diameter and aggregate cross-sectional flow area and further increasing the volume of fluid entering the greatly increased area of the swirl chamber portion of the bore 69.

Pressure relief for the chamber area behind the plunger piston 70 within which the biasing spring 73 is operative is afforded by way of a relief bore 84 of relatively small diameter extending through the axis of the plunger 70 and affording a passage from the rear end through the forward end of the plunger and in operation venting into the rear part of the swirl chamber which due to the vortex flow existing therein does not fill up toward the rear and thus affords a clear vent passage.

While the forms of the invention shown in Figures 1 and 7 provide for sealing off the spray orifice, either at the orifice or at a point between the inlet into the nozzle and the orifice or at both places, certain conditions may require that there be a constant minimum flow passage between the fluid chamber within the nozzle and the orifice. For this purpose the form of the invention shown in Figures 8 and 9 may be desirable. In this form a nozzle assembly 85 including a tubular housing or casing 87 providing an enlarged fluid chamber 88 has an inlet 89 for delivery of fluid into the chamber 88 and an end closure 90 with an axial discharge orifice 91 defined by a protruding annular lip 92. A sleeve 93 of smaller external diameter than the internal diameter of the chamber 88 abuts the closure wall 90 and affords a sliding guide for a reciprocable fluid control plunger or piston 94. Appropriate biasing means which may be of either of the forms shown in Figures 1 or 7, or any other appropriate arrangement, normally maintains the forward end or tip of the plunger 94 in abutment with the inner face of the closure wall 90 about the entrance to the orifice 91.

In order to by-pass the forward tip of the sleeve 93 for minimum fluid delivery from the chamber 88 to the orifice 91, the inner face of the closure wall 90 is formed with a set of shallow inwardly radially extending fluid delivery grooves 95 herein shown as four in number (Figure 9) and extending tangentially to the orifice 91. The grooves 95 extend from beyond the periphery of the tip of the sleeve 93 and thus afford constant communication of small aggregate flow area between the chamber 88 and the orifice 91 so that fluid will be delivered to the orifice 91 even though pressure may not be great enough to unseat the plunger 94 to open communication between the chamber 88 and a swirl chamber within the forward end portion of the sleeve 93 by way of a set of radial or tangential ports 97 opening through the sleeve. By preference the ports 97 are of substantially larger aggregate flow area than the grooves 95. As the pressure increases, the plunger 94 is unseated further until a second series of ports 98 in the sleeve 93 is uncovered. A further increase in pressure may drive the plunger 94 open to the extent that a final set of ports 99 will be open as the area of the swirl chamber increases. Through this arrangement, a swirling supply of fluid is delivered to the orifice 91 as long as there is any fluid pressure within the nozzle, and it is not necessary that a predetermined pressure build up within the nozzle before fluid is delivered as a spray from the nozzle. As the pressure increases, of course, the swirl area for the orifice 91 increases proportionately as does also the volume of fluid delivered to and through the orifice.

For certain purposes it may be highly desirable to effect a thorough fluid seal between the tip of the movable plunger and the orifice of the nozzle so as to avoid any possibility of leakage or dripping. For such purposes, the form of the invention shown in Figures 10 and 11 may be desirable. In this form a nozzle 100 having a body or casing 101 formed with a fluid chamber 102 has a closure plate or disk 103 across one end thereof and formed with an axial spray orifice 104. Integral and concentric with the closure member 103 is formed a sleeve boss 105 which projects inwardly and forms a tubular guide for a plunger or piston 107. At its forward end or tip the plunger 107 is formed with an axial frusto conical tappet valve projection 108 which in the fully seated condition of the plunger tip engages sealingly with a tapered valve seat 109 formed about the entrance to the orifice 104. Suitable biasing means, such as that shown in Figures 1 or 7, or any other preferred form of biasing means may be utilized for normally urging the plunger 107 into the sealing relation relative to the orifice 104. As in the previous forms of the invention described herein the plunger 107 may be provided with an axial small diameter bore providing a vent passage 110 which is coaxial with and vents toward the orifice 104.

Rearwardly of the valve tip of the plunger 107 the sleeve 105 is provided with fluid delivery port means communicating with the chamber 102. To this end, the sleeve 105 spaced a predetermined short distance from the plunger tip seat is formed with a pair of longitudinal slots 111 tangential to the wall of the inner bore of the sleeve. The slots 111 may be of any pre-

ferred width and length and although shown as two in number may be in any other preferred number equidistantly spaced circumferentially. Thus, when sufficient pressure has been built up within the chamber **102** to unseat the plunger **110** to the extent that the tangential slot ports **111** are uncovered fluid will issue into the swirl chamber defined between the forward end of the plunger **107** and the orifice **104** and accelerate as a vortex which flows through the orifice **104** to effect a finely atomized hollow cone spray. As the plunger **107** is moved rearwardly to increase the area of the swirl chamber, there is proportionate increase in the orifice area as the plunger progressively uncovers the port slots **111**. On the other hand, of course, there is a proportional diminution in the port slot area as the area of the swirl chamber decreases as the pressure of the fluid drops and the plunger **107** returns toward its sealing relation about the orifice **104**.

It will, of course, be understood that various details of construction may be varied through a wide range without departing from the principles of this invention and it is, therefore, not the purpose to limit the patent granted hereon otherwise than necessitated by the scope of the appended claim.

We claim as our invention:

A nozzle comprising a generally tubular housing, a member disposed in said housing adjacent one end thereof and having a longitudinal bore therethrough, said member having a longitudinally extending recess in the outer surface thereof defining with a facing portion of the inner surface of the housing a flow passage and having a transversely extending port between said recess and said bore, a flow control plunger having a portion slidable in said bore and normally closing said port and having an internal terminal end, said plunger being movable in a direction away from said one end of said housing for opening said port, a plug detachably secured in said housing adjacent the other end thereof and having an inlet port extending longitudinally therethrough, said plug having an inner terminal end longitudinally spaced from the inner terminal end of said plunger, a generally cylindrical flexible bellows sealingly connected at one end to said terminal end of said plug and at the other end to said terminal end of said plunger, the outer surface of said bellows being inwardly spaced from the facing inner surface portion of said tubular housing and defining therewith a fluid flow passageway communicating with said inlet port and said passage, said bellows being compressed by fluid under pressure from said inlet port to move said plunger longitudinally away from said one end of said opening and accommodate fluid flow through the nozzle.

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