Oct. 9, 1962 J. F. CAMPBELL 3,057,560

NOZZLE CONSTRUCTION

Filed July 19, 1960 3 Sheets-Sheet 1

FIG. 1

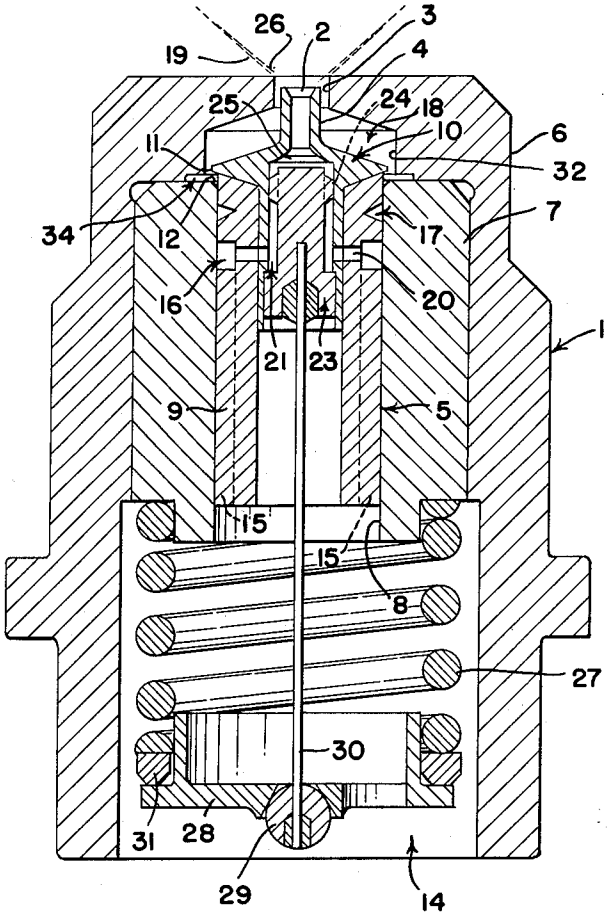
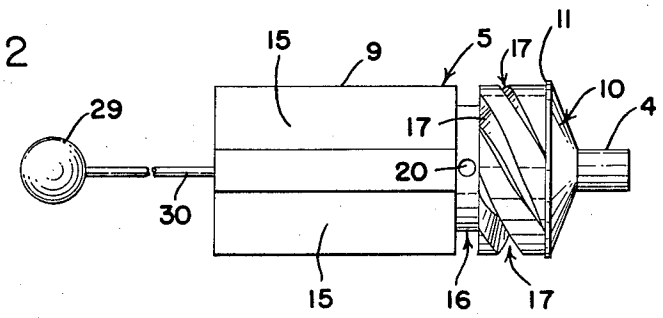


FIG. 2



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FIG. 3
PRIOR ART

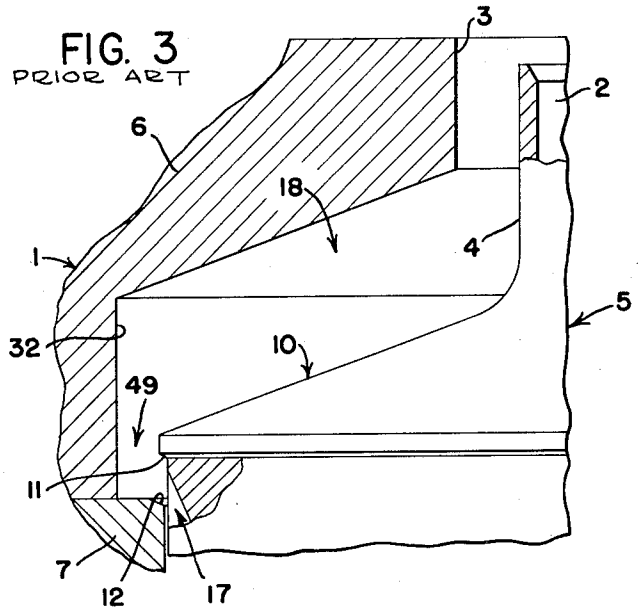
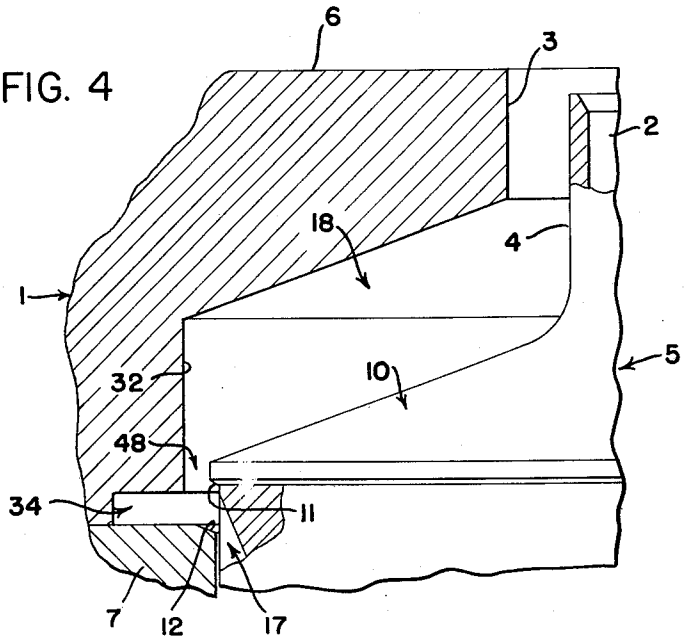


FIG. 4



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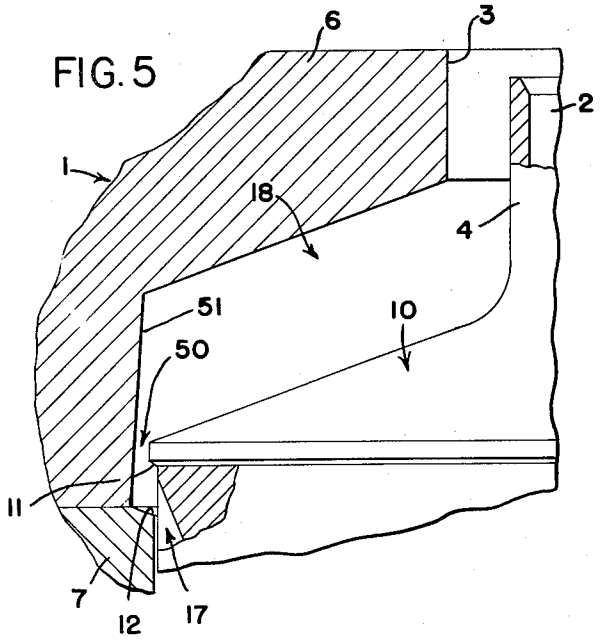
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NOZZLE CONSTRUCTION

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FIG. 5



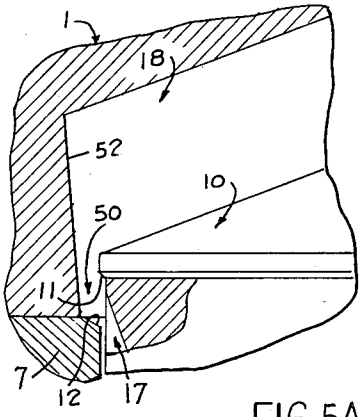
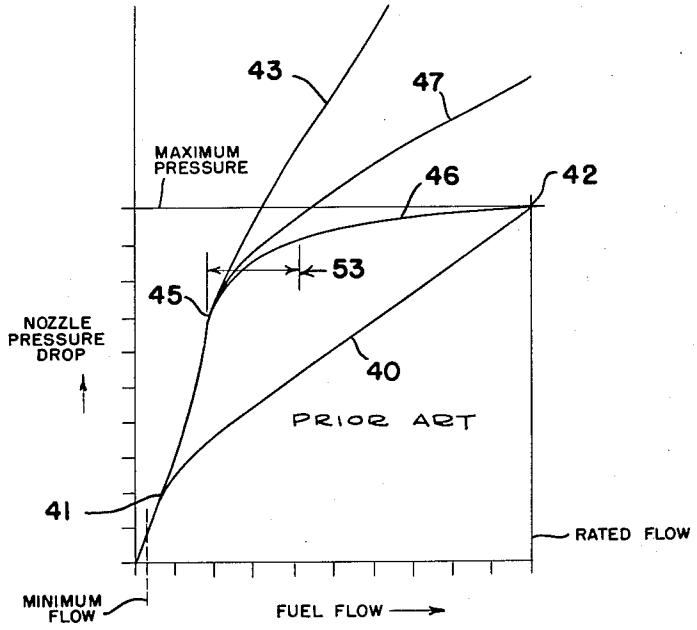


FIG. 5A

FIG. 6



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NOZZLE CONSTRUCTION

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Filed July 19, 1960, Ser. No. 43,767
1 Claim. (Cl. 239—464)

This invention relates as indicated to a nozzle construction and, more particularly, to certain improvements in open orifice spray nozzle constructions which, as disclosed in my Pat. No. 2,801,881 granted August 6, 1957, are especially adapted for the injection of liquid fuels into the combustion chambers of various types of engines.

Herein, as in the aforesaid patent, the nozzle construction is especially suitable for use in gas turbine and ram-jet engines which, at the present time, are chiefly employed in aircraft and airborne missiles although it is contemplated to employ such engines in other fields such as automotive, railroad, and marine. Broadly speaking, however, the present nozzle construction may be employed in most engines utilizing liquid fuels.

Hitherto, in nozzle constructions employed for gas turbines and ram-jet engines it has been the aim to design the nozzles to provide fuel flow versus fuel pressure curves that are initially of moderately steep slope up to about 10% rated flow and 20% rated pressure and thence decrease in slope to essentially a straight line function to 100% rated flow and pressure. To that end, these nozzles generally are provided with a primary discharge orifice to achieve proper atomization of the fuel at low pressures and flows and a secondary discharge orifice controlled by a spring-biased metering valve to achieve proper atomization of the fuel and increased rate of flow per increment of rise in pressure as compared with the flow vs. pressure characteristics of the primary orifice. There is, however, a current trend or desire on the part of engine designers to build up a relatively high pressure in the fuel supply line, say 60 to 70% of the maximum pressure while the nozzles are delivering but a small percentage of the rated flow (15–25% for example). Thereafter the nozzles would deliver a much increased rate of flow up to 100% rated flow as the pressure is increased from the 60–70% value to maximum. As related to nozzles having primary and secondary orifices, as aforesaid, this means that once the secondary orifice is cut in, the metering valve must open at a rapid rate in order to achieve 100% rated flow at the maximum pressure.

Accordingly, it is a principal object of this invention to provide a novel nozzle construction by which the aforementioned desired flow versus pressure characteristics may be achieved.

It is another object of this invention to provide in a valved nozzle construction novel means for decreasing the pressure of the fuel in the spin chamber acting on one side of the spring-closed valve in the nozzle whereby said valve moves a greater distance under the influence of the fuel inlet pressure acting on the other side of said valve to thus establish increased flow from the inlet to the orifice communicating with said spin chamber.

It is another object of this invention to provide a valved nozzle construction which has means effective to dissipate a portion of the spin energy imparted to the fuel prior to its reaching the spin chamber whereby the fuel pressure in the spin chamber is decreased with resulting decreased tendency in opposing the opening movement of the spring-closed valve under the influence of the fuel pressure in the inlet.

It is another object of this invention to provide a valved nozzle construction which has means effective to increase the pressure drop in the fuel as it flows from the nozzle to the spin chamber.

Of course, other desirable characteristics of my new nozzle include:

(*a*) Fine atomization with short penetration;
(*b*) Low supply line pressure at rated flow;
(*c*) Uniformity of composition of spray cone;
(*d*) Ability to perform well on high viscosity fuel even at temperatures of −65° F.;
(*e*) Ability to operate without change in calibration for 5000 hours operation on normal clean fuel and 150 hours on contaminated fuel between overhauls;
(*f*) Ability to match performance on a mass production basis within plus or minus 2% flow variation from a master schedule.

Other objects and advantages of the present invention will become apparent as the following description proceeds.

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

In said annexed drawings:

FIG. 1 is a longitudinal section view through a nozzle embodying the present invention, the metering valve therein being shown in partly open condition;

FIG. 2 is an elevation view of the metering valve assembly;

FIG. 3 is an enlarged fragmentary cross-section view showing the metering valve and spin chamber according to Pat. No. 2,801,881;

FIG. 4 is an enlarged fragmentary cross-section view similar to FIG. 3 but showing the metering valve and spin chamber of FIG. 1;

FIGS. 5 and 5A illustrate enlarged fragmentary cross-section views showing further embodiments of the present invention; and

FIG. 6 is a graph showing different flow versus pressure characteristics of nozzles according to the prior art and according to the present invention.

The nozzle **1** disclosed herein by way of illustrative example may be referred to as a "dual orifice" type which has a primary discharge orifice **2** and a secondary discharge orifice **3**, the orifice **2** being formed in the tubular extension **4** of the metering valve assembly **5** and the orifice **3** being formed in the nozzle body **6**.

Press-fitted or otherwise secured in the nozzle body **6** is a sleeve or liner **7** in the bore **8** of which the valve assembly **5** is axially slidably fitted. Said valve assembly **5** comprises a tubular section **9** to which the valve head **10** is secured as by press-fitting, the valve head **10** being formed with a frusto-conical seat **11** adapted to cooperate with the complemental seat **12** formed in the sleeve **7** to permit secondary flow when the valve is open from the fuel inlet passage **14** in the body **6** to the secondary discharge orifice **3** via the grooves **15**; the annular groove

16; the several helical spin slots 17 which, in conjunction with seat 12, serve to meter the flow; and the spin chamber 18. The fuel flowing through the secondary circuit as aforesaid is discharged in the form of a fine conical spray 19.

The valve head 10 and tubular section 9 are formed with registering radial openings 20 whereby fuel under pressure in inlet 14, grooves 15, and annular groove 16 flows therethrough into the annular chamber 21 around the primary swirl plug 23, and thence through the helical spin slots 24 and the primary spin chamber 25 for discharge from the primary discharge orifice 2 in the form of a fine conical spray 26.

The metering valve assembly 5 is spring-biased in a direction tending to close the secondary circuit (seats 11 and 12 in engagement) by the spring 27 which is compressed between the liner 7 of the nozzle body 6 and the spring follower 28 that engages the ball-shaped end 29 of a wire 30 which at its other end is secured to the primary swirl plug 23. One convenient way of changing the degree of compression of the spring 27 and thus changing the inlet fuel pressure at which the metering valve will be unseated to initiate flow of fuel through the secondary circuit, is to install shims 31 of different thicknesses between the spring 27 and follower 28.

The nozzle 1 thus far described may be essentially of the same type as disclosed in my Pat. No. 2,801,881 except that by comparison of FIG. 3 (similar to the Pat. No. 2,801,881) with FIG. 4 (the present construction), it can be seen that in FIG. 4 (also FIG. 1) the bore 32 of the secondary spin chamber 18 has been substantially decreased with reference to the outside diameter of the metering valve head 10, and the secondary swirl slots 17 discharge into an annular chamber or slot 34 disposed upstream between the seats 11 and 12 when the metering valve 5 is open.

Referring to FIG. 6, the curve 40 represents the typical flow versus pressure characteristics of a nozzle construction in accordance with FIG. 3 and also my Pat. No. 2,801,881. In said curve 40, the initial portion thereof up to about point 41 is the primary circuit flow alone, the metering valve 5 being held closed by spring 27. As the fuel pressure is increased, the metering valve 5 progressively opens the secondary circuit in accordance with the rate of the spring 27, whereby the total flow of fuel through the primary and secondary orifices 2 and 3 follows the portion of the curve 40 starting at about the point 41 to the end 42 thereof which represents the fuel pressure drop through the nozzle at the rated flow thereof. Of course, by increasing the compression of the spring 27, as by substituting a thicker shim 31, the flow versus pressure characteristics may be changed as represented generally by the curve 43 in FIG. 6 wherein the secondary circuit is opened at about point 45, but then it is not possible to reach the point 42 of desired rated flow at the maximum pressure. Thus, the maximum flow at maximum pressure is only about 30% of the rated flow. The portion of the curve 43 above point 45 has a steeper slope than curve 40 between points 41 and 42 because the high fuel pressures in the nozzle cause correspondingly high spin slot velocities in the secondary spin chamber 18 which, in turn, act on the metering valve 5 to prevent it from opening to the desired extent.

The curve 46 represents generally the flow versus pressure characteristics which it is desired to obtain and which has been unobtainable hitherto except at considerable added expense and difficulty of matching nozzles on a mass production basis.

To further modify the flow versus pressure characteristics of the nozzle, as represented by curve 47 in FIG. 6, and thus approach the desired curve 46, I have found that by providing the annular undercut or slot 34, opposite the exit ends of the secondary spin slots 17 between the seats 11 and 12 (when valve 5 is open) a portion of the spin velocity is dissipated therein, whereby the pressure in the secondary spin chamber 18 is decreased in magnitude whereby the metering valve 5 is permitted to open to greater extent to provide for increased flow above the point 45 of curve 47. Finally, in order to further increase the flow above point 45 of curve 46, the annular passage 48 between the bore 32 of the spin chamber and the periphery of the valve head 10 may be substantially decreased, as in FIG. 4, as compared with the corresponding annular space 49 in FIG. 3. This results in a much decreased slope of the portion of the curve 46 between points 45 and 42. Such restriction 48 further decreases the pressure of the fuel in the secondary spin chamber 18 whereby it is less effective in opposing incremental opening movement of the metering valve 5 as the inlet pressure is progressively increased. Thus, the present invention achieves the desired end, that is, the flow versus pressure characteristics of the curve 46, FIG. 6, by increased pressure drop in the fuel upstream of the secondary spin chamber 18.

In FIGS. 5 and 5A there are shown other embodiments of this invention in which the spin velocity dissipator slot 34 has been omitted but the restriction 50 is provided to decrease the pressure in the spin chamber 18 relative to the inlet pressure, whereby to procure a curve (not shown) which from about point 45 upward would be between the corresponding portions of the curves 46 and 47. A variable restriction 50 may be provided as by tapering the bore as shown by the chamber wall surface 51 in FIG. 5, which would bring the terminal portion of resulting curve nearer to curve 46 or as shown by the chamber wall surface 52 in FIG. 5A, which would bring the terminal portion of the resulting curve up higher and closer to curve 47.

It is to be noted that for any given flow rate, the reduction in pressure between the upstream and downstream sides of the metering valve 5 will vary as the ratio of the radial clearances squared. For example, if the radial clearance in FIG. 3 is eight units and that of the radial clearance in FIG. 4 is three units, then the pressure drop across the clearance is $(8/3)^2$, or about 7.1 times greater when using the clearance 48 of FIG. 4 in place of the clearance 49 of FIG. 3. The spin velocity dissipator 34 is principally effective in the low to intermediate flow range 53 while the restriction 48 upstream of the spin chamber 18 is principally effective in the intermediate to high flow range. Thus, the combination of both of these features i.e. the dissipator 34 and the restrictor 48 in my novel nozzle construction achieve the desired flow versus pressure characteristics as depicted by curve 46 in FIG. 6. It is, of course, to be understood that the curves of FIG. 6 are merely typical or illustrative of what can be achieved with the present invention. Furthermore, insofar as the broader aspects of this invention are concerned, the pressure drop increase concept whether by the dissipator 34, or by the restriction 48, or by both, may be utilized in nozzles other than those shown herein and in my Pat. No. 2,801,881. It has been found that by either increasing or decreasing the axial width of the dissipator 34 from that shown in FIG. 4 the range 53 (FIG. 6) will be either extended or shortened.

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 the following claim, or the equivalent of such, be employed.

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

In a nozzle having a fluid inlet end, an exit orifice end, a flow passage extending therebetween and means defining a spin chamber upstream of said orifice end; a spring-closed, fluid pressure actuated valve member mounted for movement in said nozzle to open and close fluid communication between said inlet end and such spin chamber, said valve member having opposite sides thereof exposed to fluid under pressure in said inlet end and such spin chamber and being formed with generally

helical slots through which fluid flows from said inlet end into such spin chamber when said valve member is in open position; and spin velocity dissipating means operative to decrease the pressure in such spin chamber comprising a lateral enlargement of the flow passage of said nozzle between such slots and spin chamber in which a portion of the spin energy imparted to the fluid is dissipated, said lateral enlargement comprising an annular undercut in the peripheral wall of such spin chamber opposite the exit end of said helical slots.

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