March 2, 1965 J. F. CAMPBELL 3,171,601

NOZZLE CONSTRUCTION

Filed Feb. 16, 1962

2 Sheets-Sheet 1

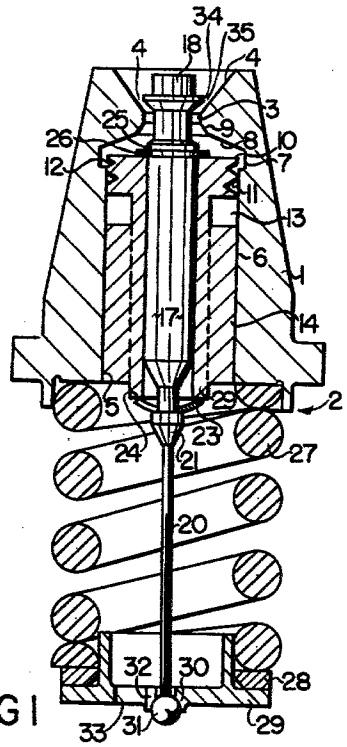


FIG 1

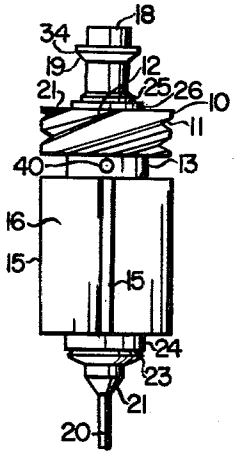


FIG 2

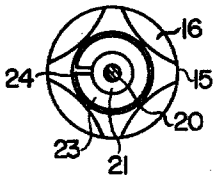


FIG 3

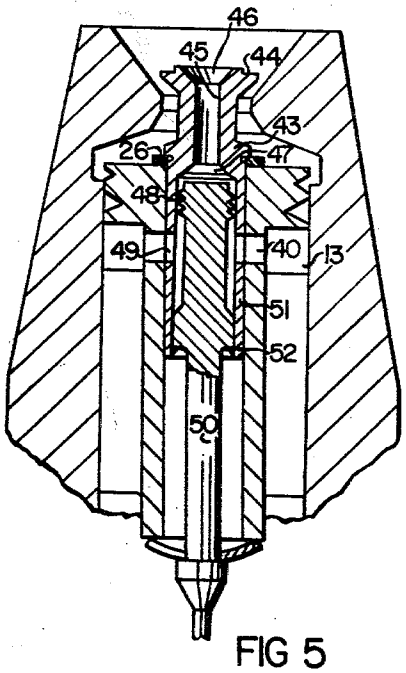


FIG 5

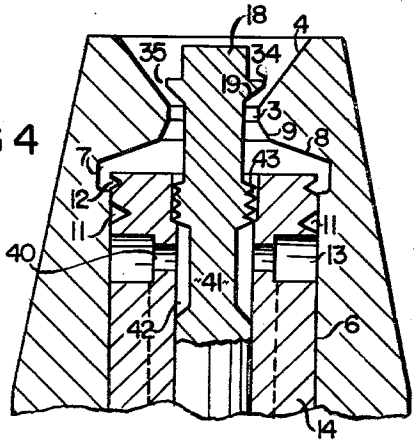


FIG 4

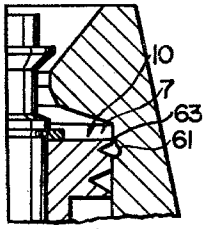


FIG 6

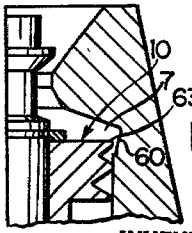


FIG 7

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NOZZLE CONSTRUCTION

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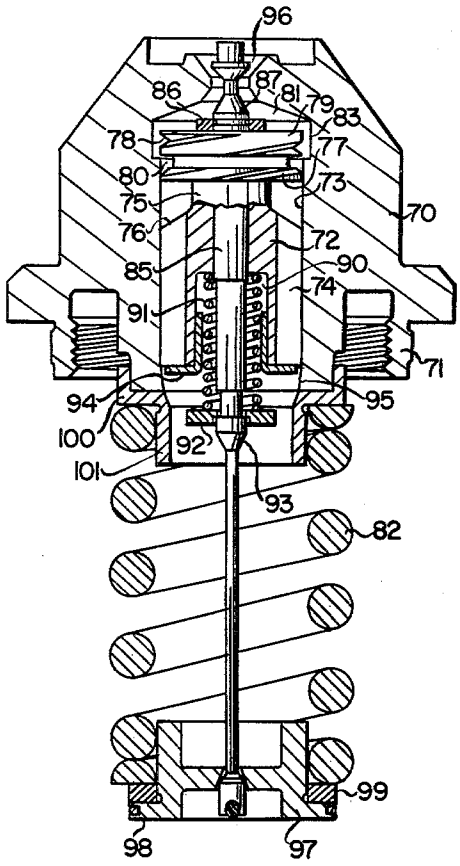


FIG 8

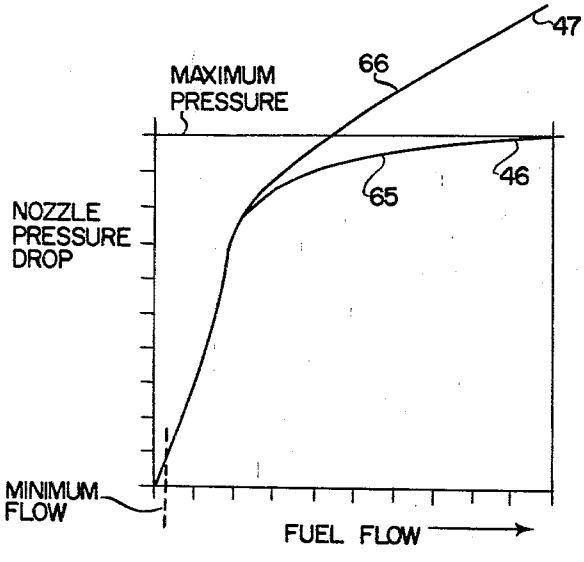


FIG 9

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NOZZLE CONSTRUCTION

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11 Claims. (Cl. 239—453)

This invention relates as indicated to a novel nozzle construction and, more particularly, to a spray nozzle especially adapted for the injection of liquid fuels into the combustion chambers of various types of engines. This application represents a continuation-in-part of my co-pending application Serial No. 43,767, filed July 19, 1960, for "Nozzle Construction," now Patent No. 3,057,560.

In my U.S. Patent 2,801,881, granted August 6, 1957, and in such U.S. application Serial No. 43,767, filed July 19, 1960, now Patent No. 3,057,560, I disclose nozzle constructions suitable for use in gas turbine and ram-jet engines which, at the present time, are chiefly employed in aircraft and air-borne missiles. The operation of high speed air-borne vehicles is now such that it is not uncommon for the temperature of the fuel in the nozzle to reach values approaching 700° F. Fuels used at present boil at this temperature unless kept at pressures of about 10 atmospheres (about 150 p.s.i.) or more. Boiling of these fuels within the nozzles can be extremely detrimental to the operation thereof since it increases the formation of sludge, varnish and solids. Such formations can cause malfunctioning of the entire fuel system.

It is therefore an object of this invention to provide an improved nozzle construction.

Another object is to provide such a nozzle for the spraying of liquid fuels into a combustion chamber adapted to operate at elevated temperatures.

A further object is to provide such a nozzle wherein the liquid fuel is prevented from boiling prior to passing the discharge end of the nozzle.

Yet another object is to provide such a nozzle which produces a finely atomized spray at a short distance therefrom, e.g., two inches from the nozzle.

A still further object is to provide such a nozzle wherein the liquid fuel is maintained under a relatively high pressure (e.g., about 150 p.s.i.) until released through the discharge orifice of the nozzle.

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 claims, the following description and the annexed drawings 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 drawings:

FIG. 1 is a longitudinal section through a nozzle embodying the principles of my invention;

FIG. 2 is an elevation view of the pintle valve assembly of FIG. 1;

FIG. 3 is an end view of the valve assembly as viewed from the left side of FIG. 2;

FIG. 4 is a fragmentary longitudinal section corresponding to FIG. 1 but showing an alternative embodiment of the valve assembly;

FIG. 5 is a fragmentary longitudinal section corresponding to FIG. 1 but showing a dual-orifice type nozzle;

FIGS. 6 and 7 are enlarged fragmentary cross-sectional views of an assembly similar to that shown in FIG. 1, showing further modifications of the present invention;

FIG. 8 is a longitudinal section of a further alternative embodiment of the present invention; and

FIG. 9 is a plot of various flow-pressure relationships obtainable with the present invention.

Two of the more important features of the instant invention are the provision of a special form of variable area exit valve of the pintle or poppet type, and, the means for varying axially the location of the pintle valve head with respect to the swirl chamber inlet valve. Since this invention is an improvement on my nozzles described in my U.S. Patent 2,801,881 and my U.S. application Serial No. 43,767, now Patent No. 3,057,560, mentioned above, all of the meritorious features of those nozzles are achieved in addition to those peculiar to the instant invention.

Referring now to FIGS. 1, 2 and 3, the embodiment of my invention there illustrated comprises an outer body portion **1** adapted to be connected with an appropriate manifold for delivery of fuel to its open end **2**. A restricted axially disposed exit orifice **3** is provided near the other end of the body portion opening into a divergent cone **4**. The body portion has a cylindrical inner bore **5** coaxial with the exit orifice **3** within which valve **6** is adapted to be fitted for axial reciprocation. The bore **5** opens into a swirl chamber **7** of larger diameter whose upper tapered conical surfaces **8** and **9** slope toward the exit orifice **3**. Valve member **6** is of generally cylindrical form but has an upper portion **10** containing helical grooves **11** of uniform disposition and cross section except in their end portions **12** approaching the swirl chamber **7**. These end portions **12** gradually taper in width and in depth and finally terminate a short distance from the annular upper end **10** of valve member **6**. Valve member **6** has an annular circumferential groove **13** therein separating its upper portion **10** from its lower portion **14**. The lower portion **14** comprises lands **15** separated by wide scallops or grooves **16** which extend longitudinally from the annular groove **13** to the open end **2** of the body portion **1**. Thus, the fuel enters the open end **2**, flows through the scallops **16** into the annular groove or chamber **13** and through the helical grooves **11** into the swirl chamber **7** and thence out through exit orifice **3** and divergent cone **4**.

The valve member **6** has a pintle shaft **17** extending axially therethrough which terminates in a pintle or poppet valve head **18** located within the divergent cone **4**. The bottom surface **19** of the pintle head is a frustum of a cone, the apex angle of which is greater than the apex angle of the divergent cone **4**.

A straight slender spring wire member **20** is secured to the pintle shaft **17**, as by welding to shouldered portion **21** of the pintle shaft **17**. The pintle shaft **17** is secured in valve member **6** as by means of a resilient spring clip **23** which is yieldably engaged between the shouldered portion **21** and the bottom end **24** of valve member **6**. The upper end of pintle shaft **17** which protrudes beyond the upper end of valve member **6** is equipped with a shoulder **25**, and a shim **26** of desired thickness is provided to axially locate the pintle head **18** with respect to the upper end **10** of valve member **6**. By the selection of shims **26** of different thicknesses, the axial relationship between the pintle head **18** and the valve member **6** may be varied. The importance of this relationship will appear hereinafter.

A preloaded compression spring **27** is coaxially seated within the inlet end **2** of the body portion **1** and bears against a shim **28** mounted on the movable seating member **29**. The latter member is provided with a central opening and conical seat **30** adapted to support ball **31** which is attached to the bottom end of spring wire member **20**. The seat **30** is slotted at **32** so that the ball **31** may pass through the opening **33** when it is desired to assemble or disassemble the component parts. The spring **27** may be a multi-coil spring machined from bar stock as shown and described in my U.S. Patent 2,749,182.

It will be obvious therefore from the foregoing description that the spring **27** will tend to hold the pintle head **18** seated within the divergent cone **4**. The outer peripheral edge **34** of the pintle head **18** will engage the surface of the divergent cone **4** in such a manner as to prevent fuel from emanating from the nozzle. Depending upon the axial relationship between the pintle head **18** and the valve member **6** as determined by shim **26**, the end portions **12** of the helical grooves **11** in the valve member **6** will protrude to a greater or lesser extent into the bottom of the swirl chamber **7** while the pintle head **18** is seated within the divergent cone **4**. This in turn will provide a varying amount of area exposed by the grooves **12** into the swirl chamber. As stated before, this can be controlled by the thickness of the shim **26**. The inlet fuel pressure will cause fuel to flow through the grooves **11** and **12** into the swirl chamber **7**. When a sufficient pressure is built up within the exit orifice **3** and acting on the under surface **19** of the pintle head **18**, the pintle head **18** will be forced upward permitting the fuel to discharge out along the surface of the divergent cone **4**. Such an arrangement ensures that the fuel will be kept under a preselected pressure (e.g., 150 p.s.i.) until it actually emanates from the nozzle. The area of the grooves **12** exposed within the swirl chamber **7**, the dimensions of the swirl chamber **7**, and the rate or characteristics of the spring **27** are all interrelated and act to determine the pressure of the fuel within the exit orifice **3** prior to its release from the nozzle. For any appropriately selected values of spring rate, swirl chamber geometry and pintle head size, there will be only one relationship between the exposed area of the helical grooves **12** within the swirl chamber **7** and the pintle opening **35** (which is the area between the circumferential edge **34** on the pintle head **18** and the adjacent interior surface of the divergent cone **4**). The design should be such that the pintle head **18** will open promptly enough in response to a fluid pressure increase to obtain at least a 0.0007 inch clearance in the pintle opening **35**. This will ordinarily produce a liquid film of sufficient thickness to maintain continuity of the film at a fairly low flow rate as may be required.

Referring now to FIG. 4, the valve member **6** is shown to contain a plurality of orifices **40** communicating with the annular chamber **13**. In addition, the pintle shaft **41** is so constructed within the valve member **6** that an annular chamber **42** is provided in communication with openings **40**. Further, the pintle shaft **41** above the groove **42** is provided with fixed area primary swirl slots **43** communicating with the groove **42** and the swirl chamber **7**. Although this particular structure does not utilize the shim **26** shown in FIG. 1, the pintle shaft **41** may be otherwise axially adjusted with respect to valve member **6**. It can be seen from this structure that fuel will flow from annular chamber **13** through openings **40** and annular groove **42**, through the fixed area primary swirl slots **43** and into the swirl chamber **7**. As the inlet pressure increases, the valve member **6** will move upwardly progressively to uncover the slots **12** for progressively increased flow through the increasing gap **35** between the pintle head **18** and divergent cone **4**.

FIG. 5 illustrates an embodiment of this invention somewhat modified from that shown in FIGS. 1 and 4 in that a primary fuel system is provided independent of that described with reference to FIG. 1. In FIG. 5, the pintle head **44** has a primary discharge orifice **45** which terminates in a divergent cone **46**. Upstream of the primary orifice **45** is a primary swirl chamber **47** and helical primary swirl slots **48** communicating with chamber **13** via radial passages **40** and **49** and chamber **42**. Pintle shaft **50** extends into the bore of the sleeve portion **51** and is fixedly attached thereto, for example by welding at **52**. In this embodiment, fuel may flow through the annular chamber **13**, registered openings **40** and **49**, annular groove **42**, fixed area helical primary swirl slots **48**, inner swirl chamber **47**, and out through inner exit orifice **45** and inner divergent cone **46**. The secondary circuit is like FIG. 1 whereby as the pintle **44** moves away from its seat there will be a prescribed pressure drop to preclude boiling of the fuel in the nozzle.

In FIGS. 6 and 7, variations are shown in the construction of the walls (surfaces **60** and **61**) of swirl chamber **7**. In FIG. 7, surface **60** is shown to have a divergent or outward taper; in FIG. 6, surface **61** is shown to have a convergent or inward taper. These variations will affect the pressure drop from the helical grooves **11** to the swirl chamber **7** which will in turn affect the slope of the plotted curve of fuel flow versus fuel pressure. These relationships are discussed in detail in my aforementioned copending application, Serial No. 43,767, filed July 19, 1960, now Patent No. 3,057,560. Thus in both the FIGS. 6 and 7 embodiments a variable restriction is provided between the annular upper end **63** of the upper portion **10** of the valve member **6** and swirl chamber **7** decreasing with valve movement in FIG. 6 and increasing with such movement in FIG. 7. With reference to FIG. 9, the curve **65** represents generally the flow versus pressure characteristics which it may be desired to obtain. The curve **66** represents the typical flow versus pressure characteristics of a nozzle construction in accordance with that shown in my aforementioned copending application. By tapering in the wall surface as shown at **61** in FIG. 6, the terminal portion of the resulting curve is brought nearer the curve **65**, or by tapering out the wall surface as shown at **60** in FIG. 7, the terminal portion of the curve is brought higher or nearer curve **66**.

Referring now to the embodiment of the invention illustrated in FIG. 8, the outer body portion **70** is provided with an annular extension **71** properly to be mounted in an engine or like housing. The valve body **72** extends longitudinally within the body **70** through bore **73** and is provided with the scallops or grooves **74** leading into an annular groove **75** which is larger at its circumferential outer extent due to the wall **76** being inclined as shown. The groove **75** corresponds to the groove **13** in the FIG. 1 embodiment. The upper portion of the valve member beyond the groove **75** is provided with helical grooves **77** of uniform disposition and cross section with the exception that their end portions **78** gradually taper in width and depth and finally terminate a short distance from the annular upper end **79** of the valve member. A uniform circumferentially annular groove **80** is superimposed on the helical grooves **77** and serves to increase the opening between such grooves and the swirl chamber **81** as the valve member **72** moves axially against the pressure of spring **82**. Thus as the pressure increases and the valve member **72** moves axially upwardly, the groove **80** will be exposed to the swirl chamber wall **83** and the spin velocity of the fluid will be somewhat dissipated.

The valve member **72** also has a pintle shaft **85** extending therethrough with shim **86** disposed between the upper end **79** of the valve body and shoulder **87** on such pintle shaft. The upstream end of the valve body is provided with an annular recess **90** housing a spring **91** which extends between the bottom of the recess and washer **92** bearing against shoulder **93** on the pintle shaft. A baffle member **94** is secured within such recess and extends substantially to cover the entry end of the scallops or grooves **74** to provide a restriction which will move with the valve body. Thus the major force on the valve member against the pressure of spring **82** will be exerted on the relatively large exposed area of the member **94**. The primary pressure drop is then at the member **94**. As noted at **95**, the wall of the bore **73** may be tapered slightly to provide a variable constriction between the baffle member **94** and the wall of the bore **73**. In the illustrated embodiment, the wall is shown as tapered inwardly so that as the valve member moves against the pressure of spring **82**, the constriction between the baffle and the wall of the bore **73** will enlarge. As in the case of the embodiment illustrated

in FIGS. 6 and 7, it will be understood that the bore wall may be tapered in the opposite direction to achieve a decreasing annular constriction area as the valve member moves against the pressure of spring 82. In this manner the variations in the annular constriction will affect the pressure drop and the relationships of the fuel flow and pressure much in the same manner as disclosed in such FIGS. 6 and 7. The valve member 72 in this embodiment is also more resiliently held against the shim 86 than in the FIG. 1 embodiment. The pintle shaft may be secured to a spring retainer 97 provided with a shoulder 98 accommodating a shim 99 supporting one end of the spring 82. The other end of the spring may be secured on the shoulder 100 of retainer 101 secured to the valve body 70.

Although the valve member as described herein has its helical grooves contained only in its top portion, a valve member having helical grooves for its entire length such as shown in FIG. 2 of my U.S. Patent 2,801,881 may be substituted therefor. Further, any suitable resilient means may be substituted for the spring 27 shown in FIG. 1.

This invention has been advantageous in providing a new nozzle construction capable of fine atomization with short penetration, low supply line pressure at rated flow, uniformity of composition of spray cone as well as an ability to perform well on high viscosity or contaminated fuels. In any event, the pressure drops in the nozzles herein are such as to prevent fuel boiling at any zone upstream of the exit orifices.

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. A nozzle having a body portion with a bore therein, said bore having an inlet end, an exit orifice near the discharge end coaxial with said bore, a swirl chamber upstream of said orifice and communicating with said bore, a cylindrical valve member fitted within said body portion for reciprocation therein, one end of said valve member protruding into said swirl chamber, a plurality of similar uniformly arranged helical grooves in the outer surface of said valve member communicating with the inlet end of said bore, said grooves tapering toward said swirl chamber in their adjacent end portions, a pintle shaft extending coaxially from said valve member through said exit orifice, a pintle head downstream of said swirl chamber on said pintle shaft of slightly greater diameter than said exit orifice, said exit orifice being upstream of said pintle head and opening into a divergent cone in said discharge end of said bore surrounding said pintle head, resilient means biasing said valve member and pintle head in an axial direction tending to seat the latter against the inner surface of said divergent cone, said helical slots in said valve member communicating said inlet end of said bore with said swirl chamber when said pintle head is in such seated position, the diameter of said pintle shaft being substantially less than the diameter of the exit orifice and the swirl chamber thereby to expose a substantial area of said pintle head to said exit orifice, and means to hold said pintle head in predetermined axially spaced relation to said valve member thus to vary the extent to which said helical slots extend into said swirl chamber when said pintle head is in such seated position.

2. The nozzle according to claim 1, wherein the axially inner surface of said pintle head is a frustum of a cone, the apex angle of which is greater than the apex angle of the said divergent cone.

3. The nozzle according to claim 1 including an annular groove superimposed on said plurality of uniformly arranged helical grooves between the ends thereof.

4. The nozzle according to claim 1 including a baffle member secured to said valve member upstream of said helical grooves against which fluid passing into said inlet end acts to move said valve member against the bias of said resilient means.

5. The nozzle according to claim 1, wherein said last-mentioned means includes a replaceable shim interposed between said pintle shaft and valve member.

6. The nozzle according to claim 1, including an inner annular chamber within said shaft, radial passages leading from each of said helical grooves to said inner annular chamber at circumferentially spaced points equidistant from the end of said valve member, swirl slots leading from said inner annular chamber to an inner swirl chamber within said shaft, a passage leading from said inner swirl chamber through said pintle head to a coaxial orifice in the end of said pintle head, said bore exit orifice opening into a divergent cone in said discharge end of said bore surrounding said pintle head, and resilient means biased normally to hold said pintle head against the inner surface of said divergent cone so that fluid flow may be only through said orifice in said pintle head until inlet pressure rises to a figure sufficient to unseat said pintle head from said divergent cone.

7. The nozzle according to claim 1, wherein said pintle shaft and pintle head are of a solid construction.

8. The nozzle according to claim 1, wherein said pintle head has a bottom surface, the length of which is substantially less than the length of said divergent cone.

9. The nozzle according to claim 5, having means disposed between said pintle shaft and valve member resiliently to hold said valve member against said shim.

10. 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 through said nozzle, 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 means at the inlet end of said valve member operative to provide a variable constriction for the passage of fluid into said inlet end according to the extent of movement of said valve member to open position.

11. The nozzle according to claim 10, wherein said last-mentioned means includes a baffle member secured to said valve member in the flow passage of said nozzle varying in cross-section area according to the extent of movement of said valve member to open position as aforesaid.

References Cited in the file of this patent

UNITED STATES PATENTS

2,656,218	Campbell	Oct. 20, 1953
2,749,182	Campbell	June 5, 1956
2,801,881	Campbell	Aug. 6, 1957
3,057,560	Campbell	Oct. 9, 1962