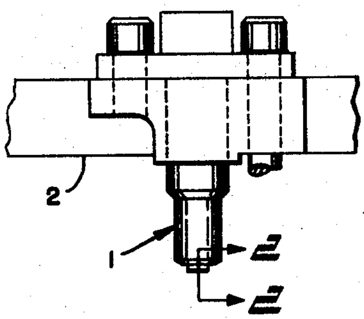
Oct. 28, 1969 H. C. SIMMONS ET AL 3,474,970

AIR ASSIST NOZZLE

Filed March 15, 1967

FIG. 2



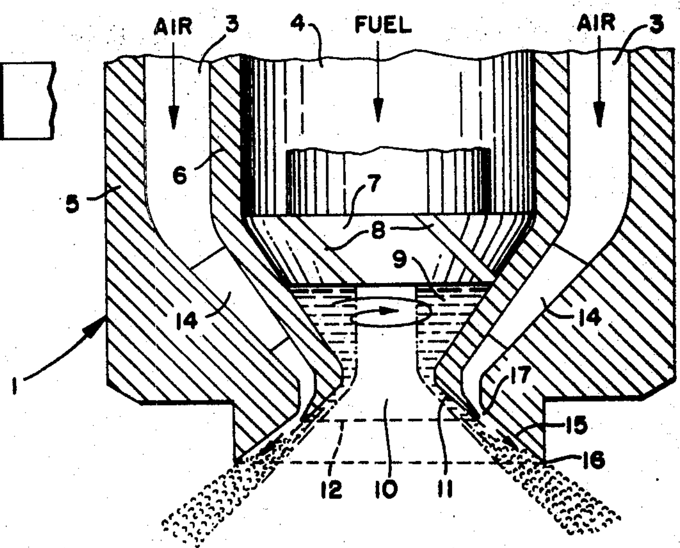


FIG. 1

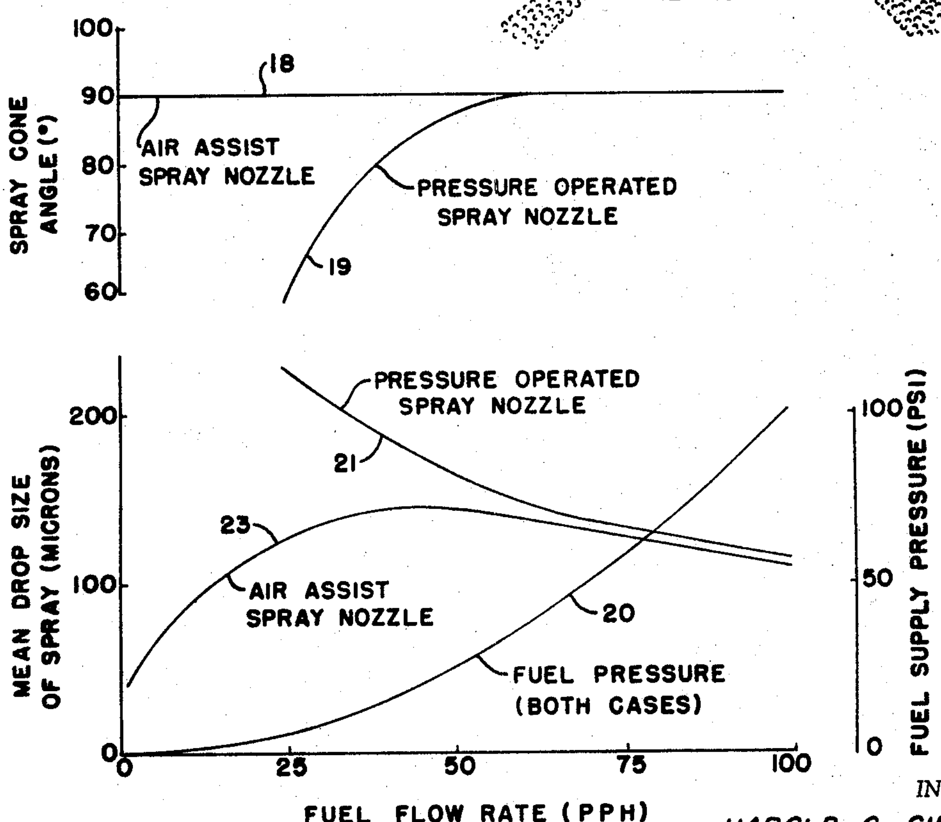


FIG. 3

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AIR ASSIST NOZZLE

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U.S. Cl. 239—404 5 Claims

ABSTRACT OF THE DISCLOSURE

Nozzle for spraying liquids especially fuel for use in aircraft gas turbines and the like. Nozzle is of air assist type characterized by merging of concentric conical air stream and conical fuel sheet at exit orifice of nozzle.

The present invention relates as indicated to a nozzle and particularly to a fuel nozzle of the air assist type for gas turbine and like application.

The nozzle herein is in the class of liquid spraying devices in which some or all of the energy required to atomize and to disperse the spray is supplied by a second fluid, such as air. Such devices take many forms with a variety of arrangements of liquid and gas passages and the gas pressures which are employed may be as high as several hundred pounds per square inch. In contrast, the present nozzle may be termed a low pressure atomizer because the air pressure required for efficient atomization ranges only from about ½ to 10 p.s.i. which pressure is especially suited for use in aircraft gas turbines in view of the difficulty and expense of providing a source of high pressure air especially under high altitude conditions.

One disadvantage of known air operated spraying devices is that the spray is concentrated in a stream of relatively small included cone angle, i.e., less than 60°, whereas, in combustion applications generally, as well as in other fields of application such as spray drying, it is necessary to produce sprays having included cone angles of the order of 90° or greater.

A known advantage of air atomizing or spraying devices is the capability of atomizing liquids of relatively higher viscosities than can conveniently be atomized by using conventional liquid pressure operated devices. In addition, because it is unnecessary to use high liquid supply pressures, the liquid passage dimensions can be made larger than otherwise required for a given flow rate, and thus the problems of clogging of passages with contaminants is minimized.

Accordingly, it is a principal object of this invention to provide an air assist nozzle which, when employed for spraying fuel for combustion engines, achieves good atomization of fuels having a wide range of viscosities, including fuels which are quite viscous at low temperatures as would be involved in high altitude flights.

It is another object of this invention to provide an air assist nozzle which improves the quality of atomization, i.e., the fineness of the spray, at very low fuel flow rates.

It is another object of this invention to provide an air assist nozzle which produces a hollow conical spray pattern of large included angle, and further, with capability of ready adjustment of the spray angle.

It is another object of this invention to provide an air assist nozzle which is economical to operate in terms of both low air pressure and low air flow rate while yet achieving good atomization.

It is another object of this invention to provide an air assist nozzle which enables the use of relatively large size fuel passages in order to minimize problems resulting from fuel contamination.

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It is another object of this invention to provide an air assist nozzle which has a very wide useful fuel flow range of, for example, 100:1 as compared with the usual 4:1 range obtainable with liquid pressure operated nozzles.

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 drawing setting forth in detail a certain illustrative embodiment of the invention, this being indicative, however, of but one of the various ways in which the principle of the invention may be employed.

In said annexed drawing:

FIG. 1 is an elevation view of a fuel nozzle embodying the present invention as mounted on an air-fuel manifold;

FIG. 2 is a fragmentary cross-section view on much enlarged scale taken substantially along the line **2—2**, FIG. 1; and

FIG. 3 are comparative graphs of performance characteristics of the present air assist nozzle and a fuel pressure operated nozzle (without air assist).

Referring now more particularly to the drawing, the nozzle **1** herein is mounted in a dual manifold **2** for supplying air and fuel into the respective passages **3** and **4** in the nozzle **1**. The nozzle **1** herein shown comprises tubular body and nozzle members **5** and **6** defining therebetween the air passage **3**. The nozzle member **6** has, in the fuel passage **4** thereof, a swirl member **7** provided with slots **8** which are disposed at an angle to the axis of the vortex chamber **9** so as to produce a swirling fuel flow having the general characteristics of a free vortex. The fuel is discharged through the orifice **10** which is coaxial with the vortex chamber **9**, the discharge orifice **10** being extended as shown in the direction of fuel discharge in a substantially conical lip **11** terminating in a sharp edge **12**.

Surrounding the vortex chamber **9** is the annular air passage **3** the inner and outer walls of which converge conically through swirl producing vanes or slots **14** in nozzle member **6** to a minimum diameter and then flares conically outward. The air flow is further guided by the lip **15** which is concentric with the vortex chamber discharge orifice **10** and terminates in the sharp edge **16**.

The cross-section area for air flow is designed to be continually decreasing until the point **17** is reached and this is made as close as is practical to the edge **12** of the fuel discharge orifice **10**. Accordingly, the highest air velocity is produced at the point **17**, and the shape of the surface **15**, in conjunction with the use of swirl slots **14** produces an air flow discharge characterized as tending to follow the surface of a cone. It should be noted that the included angles of the lips **11** and **15** are substantially the same.

In operation, when fuel enters the vortex chamber **9**, a vortex is formed having an air core as shown and the fuel discharges from the orifice **10** as a hollow conical sheet which is constrained to flow along the lip **11** and leave the edge **12** as a very thin conical sheet. At this point the thin conical sheet of fuel is immediately acted upon by the high velocity air stream and broken into a supply of small drops which continue under the combined momentum of the fuel and air streams to follow a substantially conical path until acted upon by other forces such as air turbulence. By these means, advantage is taken of the natural property of the vortex chamber **9** of tending to produce a conical sheet of fuel and the air is employed to constitute the break-up mechanism in producing a spray from the sheet.

A further important feature of the present invention is that when a high viscosity fuel is used at relatively low fuel pressure, the fuel issuing from the discharge orifice **10** has insufficient momentum to follow a conical path, but herein the high velocity air as it passes the point **17**, acts in effect as a venturi in which, by reason of the lowering of static pressure due to high air velocity, the fuel is sucked outward following lips **11** and **15**, and is atomized by the air stream. This characteristic is demonstrated in FIG. 3 which shows that the supply cone angle can be maintained by the air assist nozzle **1** down to very low fuel flow rates. In fact, this flow rate is far below the point at which a conventional fuel pressure operated nozzle ceases to produce a recognizably conical discharge.

In the design of the fuel vortex chamber **9** the inlet passage **4** and discharge orifice **10** dimensions can be chosen without regard to the atomizing process. In other words, the dimensions can be maximized and low fuel spray pressures employed. The geometry and sizes of the air flow passage **3** do not appear to be critical until the point **17** is reached and it has been found that the width of the air annulus at point **17** should be of the same order of magnitude as the dimensions of the fuel inlet slots **8** thus indicating no greater precision to be required in the manufacture of the air passages **3**, and **14** than in the parts of the fuel vortex chamber **9**. The effectiveness of this nozzle **1** in producing finely atomized sprays is due to the high kinetic energy of the air stream. For example, for equal flow rates of air and fuel and an equal pressure drop for both fluids the kinetic energy of the air can be shown to be about 600 times greater than the fuel. In a specific example, therefore, where it is required to atomize a fuel flow rate of 1 p.p.h., the fuel pressure being no greater than 1 p.s.i., if 1 p.p.h of air at a pressure drop of 1 p.s.i is supplied, the atomizing power of the nozzle **1** is similar to that which would be produced by a pressure operated fuel nozzle operating at about 300 p.s.i. fuel pressure. In practice, the pressure operated nozzle would have extremely small dimensions and would be very limited in the flow range available without using very high fuel pressures.

In the present nozzle **1** the cone angle of the spray can readily be changed by simply changing the angles of the lips **11** and **15** without changing the proportions of the fuel vortex chamber **9** or the internal air passages **3** and **14**.

Referring to FIG. 3, it can be seen that with the present nozzle **1** the spray cone angle (curve **18**) remains substantially constant, i.e., 90° at all fuel flow rates between 0 and 100 p.p.h., whereas, a fuel pressure operated nozzle for a 90° spray cone angle (curve **19**) does not attain that spray cone angle until the flow is about 60 p.p.h., the angle gradually increasing to 90° from about 60° at 25 p.p.h.

In FIG. 3 the curve **20** represents the fuel supply pressure vs. fuel flow rate characteristics of both the nozzle **1** of the present invention and a conventional fuel pressure operated nozzle. With reference to fuel flow range, the conventional fuel pressure operated nozzle (curve **21**) has a useful flow range of about 4:1 with an average droplet size of about 120 microns at 100 p.p.h. with the droplet size increasing to about 220 microns at 25 p.p.h., that being the limit of a usable fuel spray. Contrary to that, the present nozzle **1** (curve **23**) has a usable flow

range of about 100:1, since from a rate of fuel flow of just greater than 0 p.p.h. the droplet size ranges from less than 50 microns at such low flow to a maximum of about 140 microns at about 40 p.p.h. flow and then gradually down to about 120 microns at 100 p.p.h.

With the present nozzle **1** even with a high viscosity fuel at low temperature there is no problem in relighting the engine even at 25,000′ altitude. At high rates of fuel flow it has been found that the air flow can be discontinued if desired, although the results are better with swirling low pressure air. In some cases satisfactory results may be obtained by omitting the air swirl slots **14**.

In any case, it has been found that only a low air pressure of from ½ to 10 p.s.i. is required and in the curves of FIG. 3, the air pressure was but 1 p.s.i. and the fuel has a viscosity of 12 centistokes.

We therefore particularly point out and distinctly claim as our invention:

1. A spray nozzle comprising a nozzle body assembly defining therewithin a liquid passage having a vortex chamber to impart a whirling motion to the liquid flowing through said passage and having an outwardly flared conical discharge orifice through which the liquid is discharged in the form of a hollow cone, and an annular air passage disposed concentrically around said orifice for flow of air to merge with the liquid cone as the latter flows past the end of said discharge orifice thus to break up the liquid into a fine conical spray, the wall of said discharge orifice and the inner wall of said air passage converging toward each other, said air passage being of minimum radial cross-section width substantially at the end of said orifice, and the outer wall of said air passage extending radially and axially beyond the end of said discharge orifice thus to form a conical surface having an included angle substantially the same as the included angle of the orifice along which the air stream flows to assist in break up of the liquid as it leaves the confines of said orifice.

2. The spray nozzle of claim **1** wherein said air passage has converging conical inner and outer walls effective to impart high velocity flow of air as it merges with the liquid.

3. The spray nozzle of claim **2** wherein said air passage has spin slots therein to impart whirling motion to the air as it merges with the liquid.

4. The spray nozzle of claim **2** wherein said inner and outer conical walls immediately upstream of the end of said orifice are flared outwardly to turn the increasing velocity air flow therethrough so as to flow in the form of a conical stream along the liquid as the latter leaves the confines of said orifice.

5. The spray nozzle of claim **4** wherein the outwardly flared inner wall of said air passage merges with said orifice to locate said air passage closely adjacent the edge of said orifice.

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