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A. TINI ET AL
HOLLOW CONICAL FUEL SPRAY NOZZLE FOR
PRESSURIZED COMBUSTION APPARATUS

3,302,399

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2 Sheets-Sheet 1

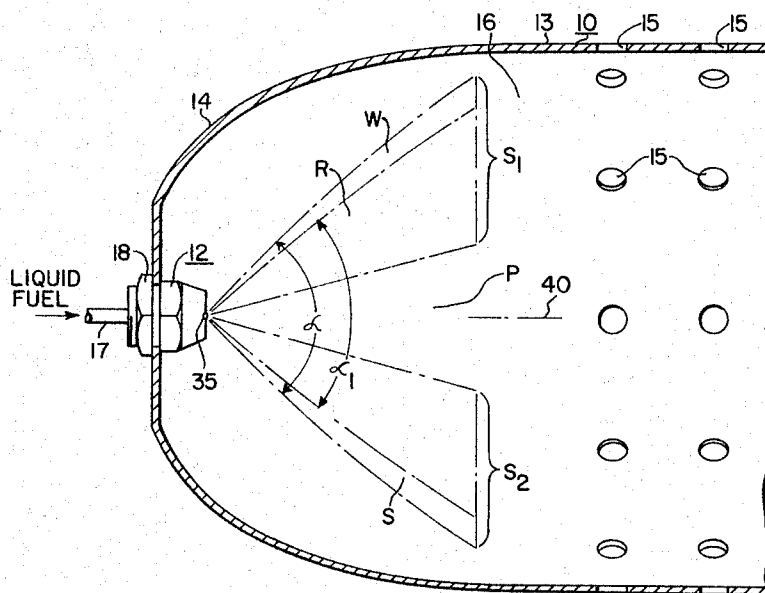


FIG. 1.

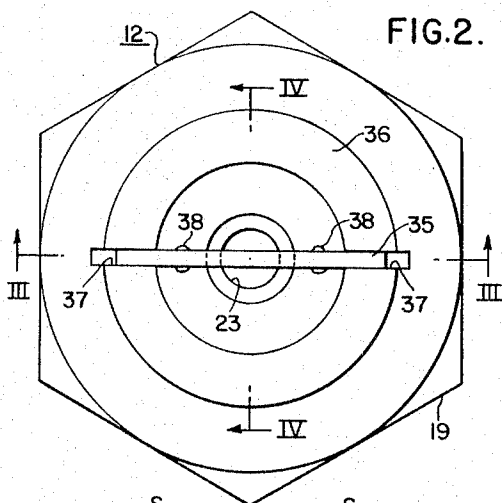


FIG. 2.

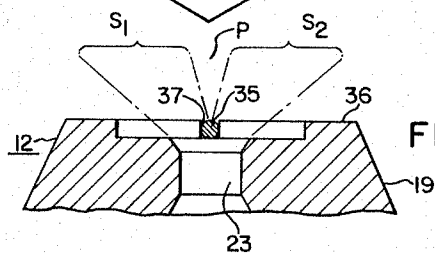


FIG. 4.

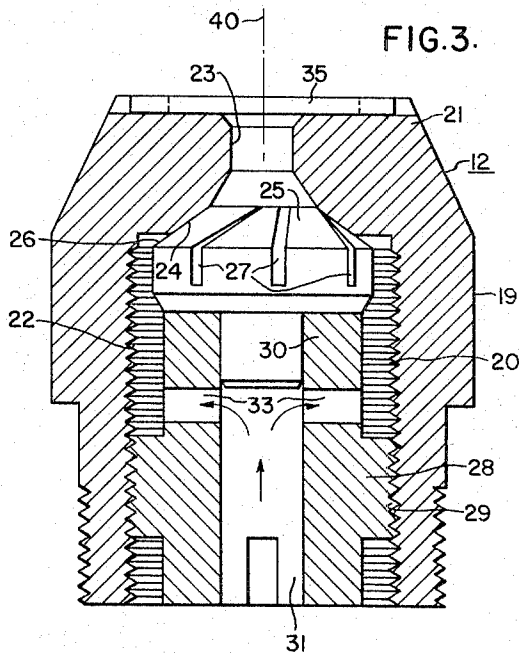


FIG. 3.

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2 Sheets-Sheet 2

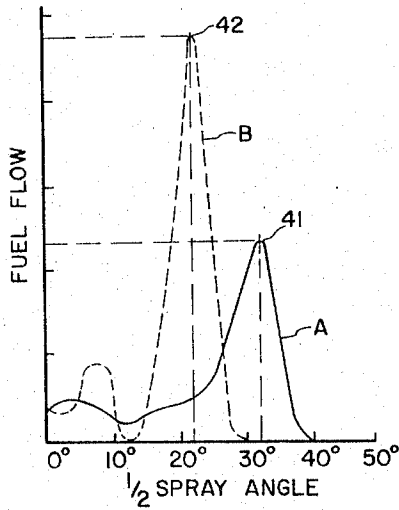


FIG. 6.

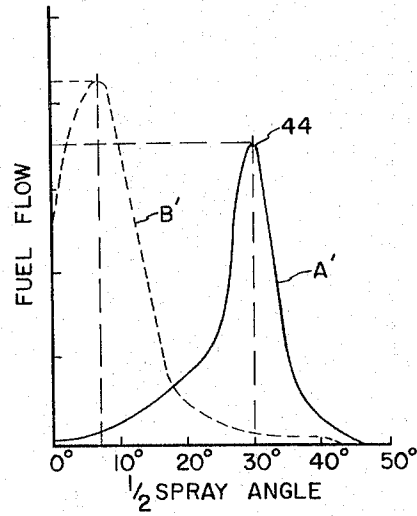


FIG. 5.
PRIOR ART

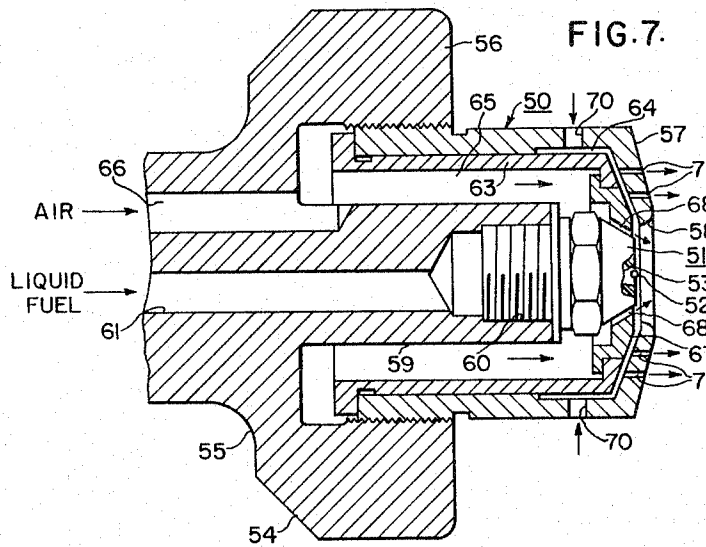


FIG. 7.

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HOLLOW CONICAL FUEL SPRAY NOZZLE FOR PRESSURIZED COMBUSTION APPARATUS

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12 Claims. (Cl. 60—39.74)

This invention relates to nozzles for spraying a liquid in a hollow conical spray and has for an object to provide an improved nozzle of this character.

Liquid spray nozzles have many applications, an important one being to spray a liquid fuel into the combustion apparatus of a gas turbine to form a combustible fuel and air mixture. For optimum fuel and air mixing, the liquid is directed from the nozzle in a hollow conical spray pattern. Also, for fuel combustion purposes, the spray angle or central angle of the spray cone is preferably a wide angle (about 80°) to promote distribution of the liquid.

With conventional wide angle liquid spray nozzles employed in gas turbines, since the combustion chamber is in a highly pressurized state, it is extremely difficult to maintain the hollow conical spray required for proper distribution of the liquid. At the higher combustion chamber pressures currently employed, the spray angle narrows and the conical pattern tends to collapse, with ensuing poor liquid distribution and poor liquid and air mixing, especially at high fuel flow rates, thereby adversely affecting combustion and causing uneven combustion chamber outlet temperature distribution.

It has been found that when a liquid spray nozzle of the above type is employed in a gas turbine combustion chamber, the region within the conical spray envelope attains a lower pressure than the ambient pressure of the combustion chamber, and the resulting differential in pressure therebetween is primarily responsible for the ensuing instability of the spray pattern and its tendency to collapse.

In view of the above, it is a principal object of the invention to provide a nozzle for spraying liquid in a hollow conical pattern in which the spray pattern is more stable than heretofore.

Another object is to provide a nozzle of the above type in which the tendency for the hollow conical spray to collapse, when disposed in a highly pressurized ambient, is minimized.

A further object is to provide a spray nozzle of the above type having means for reducing the differential pressure across the spray envelope.

In accordance with the invention, the improvement resides in providing means such as a rod member extending across the spray orifice of a liquid spray nozzle having the characteristic of spraying the liquid in a hollow conical spray pattern. The rod member is effective, in operation to divide the spray envelop into at least two spaced portions. The space between the portions is effective to provide a path for air at the ambient pressure surrounding the spray envelope to enter the region within the envelope, thereby minimizing the differential pressure and enhancing the stability of the conical spray pattern.

The internal structure of the spray nozzle may be conventional. For example, when the spray nozzle is of the well known centrifugal type, the usual swirl element may be provided for imparting an initial swirl to the liquid before it is directed to the spray orifice.

The above and other objects are effected by the invention as will be apparent from the following description

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and claims taken in connection with the accompanying drawings, forming a part of this application, in which:

FIGURE 1 is an axial sectional view of a portion of a gas turbine combustion chamber having a fuel spray nozzle incorporating the invention;

FIG. 2 is an enlarged front end view of the nozzle shown in FIG. 1;

FIG. 3 is an axial sectional view taken on line III—III of FIG. 2;

FIG. 4 is a fragmentary axial sectional view taken on line IV—IV of FIG. 2;

FIG. 5 is a chart illustrating representative flow conditions attained with a prior art nozzle;

FIG. 6 is a chart similar to FIG. 5 but illustrating flow conditions attained with the invention; and

FIG. 7 is an axial sectional view illustrating another embodiment of the invention.

Referring to the drawings in detail, in FIG. 1 there is shown the upstream end portion of a combustion chamber 10 provided with a liquid spray nozzle 12 in accordance with the invention. The combustion chamber is shown partially, since it may be of any suitable type employed for generating pressurized hot gaseous products of combustion for motivating a gas turbine (not shown).

The combustion chamber 10, in the illustration, is of the canister type and includes a tubular body portion 13 and an upstream end wall portion 14 of cup shape. The body portion 13 is provided with a plurality of spaced circumferential apertures 15 through which compressed air for combustion is admitted to the combustion space 16. The spray nozzle 12 is supplied with liquid fuel from any suitable supply (not shown) by a conduit 17 and is employed to inject pressurized liquid fuel in atomized form into the combustion space 16. The nozzle is secured in the end wall 14 in any suitable manner, as by a lock nut 18.

As best illustrated in FIG. 3, the nozzle 12 is of the centrifugal type and is provided with an external body 19 having a cylindrical cavity 20 defined at one end by an end wall portion 21 of the body and provided with internal threads 22.

The end wall 21 is provided with a centrally disposed, circular fuel discharge orifice 23, partially defined at its innermost end by a frustoconical surface 24. A swirl member 25 having a mating frustoconical surface 26 is seated on the surface 24 and is provided with a circular array of skewed slots 27.

The swirl member 25 is maintained in tightly seated position by a cylindrical locking member 28 having external threads 29 mating with the internal threads 22 and a portion of reduced diameter 30 bearing against the swirl member. The locking member 28 has an axial passageway 31 connectable to the fuel supply conduit 17 (FIG. 1) and a plurality of transverse passageways 33.

The fuel nozzle 12, as thus far described, is substantially conventional and operates in the following manner. Pressurized liquid fuel is directed by the conduit 17 into the passageway 31 to the passageways 33, thence to the annular portion of the cavity 20 (between the threads 22 and the portion 30 of the locking member 28), through the skewed slots 27, to the orifice 23. As the liquid is divided into a plurality of fine whirling streams by the slots 27, the liquid issues from the orifice 23 in atomized form as a hollow conical spray.

In accordance with the invention, the nozzle body 19 is provided with a rod member 35 positioned in such a manner that it extends diametrically across the discharge orifice 23. The rod member is of smaller transverse width than the diameter of the orifice and may be attached to the body 19 in any suitable manner. However, as illustrated, the end face of the body is provided with an annu-

lar rib 36 concentric with the orifice 23 and the rib is provided with diametrically opposed grooves 37. The opposed end portions of the rod 35 are received in the grooves 37 and secured to the body 19 by brazed joints 38.

During operation, as illustrated in FIGS. 1 and 4, the liquid emerges from the nozzle 12 in atomized spray form and the spray defines a hollow conical spray pattern S having an outer apical or conical angle α of about 80°. The spray pattern S is in the form of a hollow conical sheath of gradually increasing width, as indicated by W, so that the inner conical angle α_1 is smaller than the outer conical angle α . The outer conical angle α is called the rated spray angle. However, for flow test purposes, the "equivalent flow angle" is considered the most important criterion, since it is the angle at which the greatest spray flow occurs, and is intermediate α_1 and α .

The rod member 35 is effective to bisect the conical pattern S into two hemi-conical portions S_1 and S_2 , separated from each other by a pair of diametrically opposed angular spaces or gaps P (only one shown) having substantially no flow.

Accordingly, during combustion conditions, with high ambient pressures in the combustion space 16, the aerodynamic effects of the spray pattern S tend to create a reduced pressure within the region R. However, the differential pressure between the ambient in the combustion space 16 and the region R is relieved, since the spaces provide paths for permitting equalizing flow of the pressurized combustion air thereinto.

Hence, the spray pattern S tends to be more stable than heretofore with reduced tendency to narrow the inner and outer spray angles α_1 and α , respectively. This results in more stable distribution of the liquid spray, into the combustion space 16 with attendant improved combustion.

Although the rod member 35, as illustrated, is of circular cross-sectional aspect, it may be of any other suitable cross-sectional shape, such as elliptical, rectangular or triangular, for example. The transverse width of the rod is not critical. However, from tests, it appears that the optimum transverse width for the rod is that which provides the spaces P with an angular divergence of from about 30° to 45°, with a fuel pressure drop of about 100 p.s.i. across the orifice 23.

FIGS. 5 and 6 are graphs illustrating typical flow conditions attained with a conventional nozzle and with the invention, respectively, for comparison purposes. The two nozzles tested were substantially identical in all aspects, except that the one employed in arriving at the curves shown in FIG. 6 was modified and provided with the spray cone dividing rod member 35. In attaining the two sets of graphs above, the fuel pressure drop across the orifices was maintained at 100 p.s.i.g. (pounds per square inch gauge).

Referring to FIG. 6, it will be seen that the abscissa is labeled "½ Spray Angle" and the ordinate is labeled "Fuel Flow." That is, the fuel flow rates are indicated for ½ of the fuel spray pattern S, with the 0° abscissa taken at the central axis 40 of the orifice (FIGS. 1 and 3). The other half of the spray pattern is substantially the same and is not shown, for simplicity.

In FIG. 6, there are shown two curves A and B. The curve A was attained at an ambient pressure of 29.7 p.s.i.a. (pounds per square inch absolute), or slightly more than two atmospheres. It will be seen that the highest about 41 on curve A was attained at about 32°, so that the "effective" spray angle is about 64°, while the greatest ½ angle at which fuel flow was attained is about 40°, so that the rated angle α is about 80°. As mentioned previously, the effective angle is the important criterion in evaluating spray characteristics of a nozzle and is a value intermediate angles α and α_1 .

The curve B was attained at a considerably higher ambient pressure of 119.7 p.s.i.a. or slightly more than 8 atmospheres. The highest point 42 on this curve occurred

at about 23°, so that the effective spray angle is about 46°, and the maximum ½ angle at which fuel flow occurred was about 30° so that the rated angle α is about 60°.

In other words, with the invention, the rated spray angle diminished from 80° to 60° (about 25%) while the effective spray angle diminished from 64° to 46° (about 29%).

Referring to FIG. 5, there are shown two curves A' and B'. The curve A' was attained at an ambient pressure of 28.6 p.s.i.a. or about two atmospheres. The highest point 44 on curve A' was attained at about 30°, so that the effective spray angle is about 60°, while the greatest ½ angle at which fuel flow was attained is about 47°, so that the rated spray angle is about 94°.

The curve B' was attained at a much higher ambient pressure of 114.3 p.s.i.a. or slightly less than 8 atmospheres. The highest point on this curve was attained at about 7½°, so that the effective spray angle is about 15°, and the maximum half angle at which fuel flow occurred was about 43°, so that the rated angle is about 86°. Accordingly, the rated spray angle diminished from 94° to 86° (about 9%), while the effective spray angle diminished from 60° to 15° (about 75%).

Comparing the above it will be noted that even though the rated spray angle decrease at high ambient values appears to be greater with the invention (25% vs. 9%), the effective spray angle decrease is considerably less (29% vs. 75%). Accordingly, a great improvement in stability of fuel spray distribution is attained with the invention.

Although, FIGS. 5 and 6 illustrate only two sets of curves for comparison, other curves attained at intermediate ambient pressures (not shown) indicate consistently proportionately improved results with the invention.

FIG. 7 illustrates a liquid spray nozzle structure 50 embodying another modification of the invention. The nozzle structure 50 is of the type known as an "air-assisted" nozzle and includes a centrifugal fuel spray nozzle 51 substantially identical in structure and operation with the nozzle 12 already described having a rod member 52 extending across the discharge orifice 53. Accordingly, the internal detail structure of the nozzle 51 is not again illustrated.

The nozzle structure 50 further includes a body 54 comprising a mounting member 55 (partially shown), having an internally threaded flange portion 56 and a cap or outer thimble member 57 threadedly connected to the flange portion 56. The thimble 57 has an orifice 58 of larger diameter than the orifice 53 and concentric therewith. The flange portion 56 further comprises a tubular portion 59 having an internally threaded cavity 60 disposed in communication with a passage 61 and having the liquid spray nozzle 51 threadedly attached thereto.

The thimble 57 has an internal thimble member 63 nested therein and, jointly therewith, there is defined an annular converging passageway 64 communicating at one end with the orifice 58. An internal space 65 jointly defined by the internal thimble 63 and the cylindrical portion 59. This space is disposed in communication with an air supply passageway 66 and an annular swirl plate 67 is disposed between the nozzle 51 and the thimble 63. The swirl plate 67 is provided with an annular array of skewed apertures 68.

In operation, pressurized liquid from a suitable supply (not shown) is directed by the passageway 61 to the spray nozzle 51 and discharged therefrom in a hollow conical spray divided into two portions by the rod member 52, as described in conjunction with the first embodiment.

Concomitantly therewith, pressurized air from a suitable supply (not shown) is directed by the passageway 66 to the space 65, thence through the skewed aperture 68 with a swirling action, and finally discharged in an annular envelope about the liquid spray from the orifice

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53. The atomized liquid spray is thus further atomized by the enveloping air flow and is finally directed through the orifice 58.

The outer thimble 57 is further provided with an annular array of intake apertures 70 and a plurality of annular rows of outlet apertures 71 surrounding the orifice 58. During operation, as described above, ambient air is aspirated by the intake apertures 70 and discharged in a plurality of discrete jets by the outlet apertures 71 to keep the outer surface of the thimble 57 substantially free of combustion product deposits.

It will now be seen that the invention provides a simple, yet highly effective, arrangement for improving the spray characteristics of a liquid spray nozzle structure. Further, that the spray characteristics of a liquid spray nozzle employed in conjunction with a higher than atmospheric ambient pressure are enhanced, so that when liquid fuel is thus sprayed into a pressurized combustion chamber, the air and fuel mixture is improved with resulting uniformity of combustion.

Although two embodiments are shown, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof.

We claim as our invention:

1. A fuel spray nozzle for spraying pressurized liquid fuel into a pressurized combustion chamber, said nozzle having a body defining a circular orifice, means for supplying liquid fuel to said body, means including a swirl member disposed within said body for directing the liquid through said orifice in a hollow conical spray pattern having a predetermined spray angle at atmospheric pressure, and means extending across said orifice and rigidly attached to said body for dividing the hollow spray into at least two portions, whereby during operation in a pressurized chamber the reduction in said spray angle is minimized.
2. The structure recited in claim 1 in which: the dividing means is an elongated member of smaller transverse width than the diameter of the orifice.
3. The structure recited in claim 1 in which: the dividing means is an elongated rod of smaller transverse width than the diameter of the orifice and is disposed in diametric relation with the orifice, thereby to divide the hollow spray into two substantially equal conical portions.
4. A fuel spray nozzle for spraying pressurized liquid fuel into a pressurized combustion chamber, said nozzle having a body defining a circular orifice, means for supplying liquid to said body, means including a swirl member disposed within said body for directing the liquid through said orifice in a hollow conical spray pattern having a predetermined spray angle at normal atmospheric pressure, and a rod member recessed in said body and extending diametrically across said orifice, said rod member being effective to divide the hollow spray into two hemi-conical portions, whereby during operation in a pressurized chamber said spray angle is substantially sustained.
5. The structure recited in claim 4 in which: the rod member is of smaller width than the diameter of the orifice.
6. The structure recited in claim 4 in which: the rod member is of triangular cross-sectional shape and is of smaller width in a plane parallel to the plane of the orifice than the diameter of the orifice.
7. In a fuel combustor having a casing defining a combustion chamber, means for admitting pressurized air to said chamber to provide a super-atmospheric ambient pressure for combustion, and

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a nozzle having a body defining an orifice for injecting pressurized fuel into said combustion chamber in a hollow conical spray pattern having a central spray angle to provide a combustible mixture,

the improvement comprising

means extending across said orifice and rigidly attached to said body for dividing the hollow spray into at least two portions and effective to reduce the tendency of the super-atmospheric ambient in said chamber to decrease said spray angle.

8. The structure recited in claim 7 in which:

the dividing means is an elongated member of smaller transverse width than the diameter of the orifice and having both of its end portions attached to the body.

9. The structure recited in claim 7 in which:

the dividing means is an elongated member of smaller transverse width than the diameter of the orifice and is disposed in diametric relation therewith, thereby to divide the spray into two substantially equal hollow conical portions.

10. In a fuel combustor for a gas turbine having

a casing defining a combustion chamber,

means for admitting pressurized air to said chamber to provide a super-atmospheric ambient pressure, and

a nozzle having an annular wall defining an orifice for injecting pressurized liquid fuel into said chamber in a hollow conical spray pattern having a central spray angle to provide a combustible mixture with said pressurized air,

the improvement comprising

means rigidly attached to said wall and extending across said orifice to divide the hollow spray into at least two portions and effective to reduce the tendency of the super-atmospheric ambient pressure in said chamber to decrease said spray angle.

11. The structure recited in claim 10 in which:

the dividing means is an elongated member of smaller transverse width than the diameter of the orifice and is effective to divide the spray into at least two equal conical portions about the central spray angle.

12. The structure recited in claim 1 and further including

a second body structure surrounding the previously mentioned body and at least partly defining an annular flow passage,

means for supplying pressurized air to said annular passage,

the swirl member being interposed between the two bodies and encompassing the orifice,

said swirl member having an annular array of skewed apertures for directing air about the conical fuel spray, and

means for aspirating air into said second body and ejecting said aspirated air in a plurality of discrete jets about the fuel spray, in a manner to maintain at least a portion of the outer surface of said second body free of combustion product deposits.

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