(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 939 275 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
01.09.1999 Bulletin 1999/35

(21) Application number: **98310791.3**

(22) Date of filing: **30.12.1998**

(51) Int. Cl.^{6}: **F23C 7/00**, F23C 5/02, F23D 11/10, F23R 3/10, F23R 3/28

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **30.12.1997 US 897**

(71) Applicant:
UNITED TECHNOLOGIES CORPORATION
Hartford, Connecticut 06101 (US)

(72) Inventors:
- **Rup, John J. Jr.**
Willington, Connecticut 06279 (US)
- **Hoke, James B.**
Tolland, Connecticut 06084 (US)

(74) Representative:
Leckey, David Herbert
Frank B. Dehn & Co.,
European Patent Attorneys,
179 Queen Victoria Street
London EC4V 4EL (GB)

(54) Fuel nozzle and nozzle guide for gas turbine engine

(57) A fuel nozzle/guide assembly for a gas turbine engine for reducing NOx emissions has a central axial inflow swirler (32) and either three concentric radial inflow swirlers (34, 62, 88) or, alternatively, two concentric radial inflow swirlers (34, 62) and a concentric array of air passages (74), for rapid uniform fuel-air mixing downstream from the fuel injector.

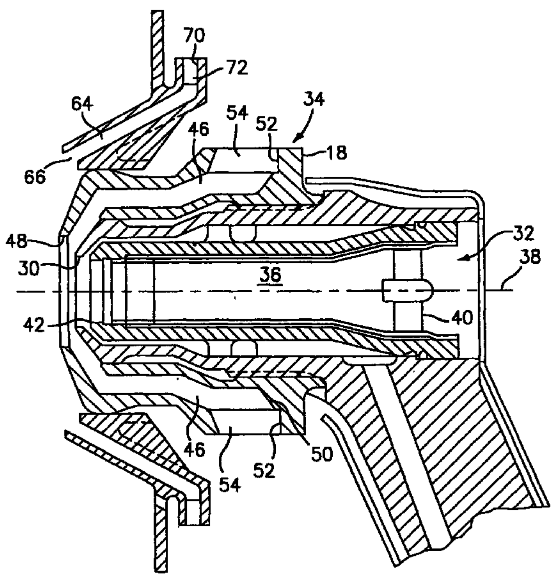

FIG. 1

EP 0 939 275 A2

Description

[0001] This invention relates generally to gas turbine engine combustors and more particularly to a fuel nozzle and nozzle guide for use in such a combustor.

[0002] Gas turbine engines emit various pollutants including oxides of nitrogen ("NOx"). NOx is primarily formed through the thermal fixation of nitrogen and results from the high temperature combustion of fuel and air in the gas turbine engine. Environmental concerns and more stringent governmental regulation of NOx emissions have prompted designers to investigate various methods for reducing the generation of NOx by gas turbine engines. Illustrative devices for reducing or controlling NOx are disclosed in the following commonly-assigned patents: (1) Snyder et al., US 5256352 issued 26 October 1993 entitled "Air-Liquid Mixer"; (2) Mcvey et al., US 5263325 issued 23 November 1993 entitled "Low NOx Combustion"; and (3) Marshall, US 5406799 issued 18 April 1995 entitled "Combustion Chamber".

[0003] Two basic approaches for a low NOx fuel injection system are (1) a locally lean stoichiometry system and (2) a locally rich stoichiometry system. Both approaches require good atomisation, mixing and uniformity in the fuel-air mixture. It is therefore desirable to provide a fuel injection system with improved atomization, mixing and/or uniformity.

[0004] According to an aspect of the present invention, there is provided a fuel injection nozzle/guide assembly having a fuel delivery passage with a discharge outlet for discharging fuel, a first axial inflow swirler with a first outlet positioned to provide swirled air to the discharged fuel, a second radial inflow swirler with a second outlet positioned to provide swirled air to the discharged fuel to produce a downstream-flowing fuel-air mixture, and a third radial inflow swirler with a third inflow swirler with a third outlet positioned to provide swirled air to the downstream-flowing fuel-air mixture.

[0005] The angular swirl direction of each swirler may be selectively determined to provide co-swirling or counter-swirling dependent upon application. In one embodiment, a fourth radial inflow swirler is disposed with a fourth outlet about the third swirler outlet or alternatively a plurality of axially extending air passages with outlet ends are disposed about the third swirler outlet.

[0006] According to a second aspect of the present invention, there is provided a fuel nozzle for a gas turbine engine, having a base, a head, a fuel delivery passage having a discharge outlet for discharging fuel, an axial inflow swirler in the head having an outlet for directing swirled air to the discharge outlet, and a radial inflow swirler having an outlet for directing swirled air to the discharge outlet.

[0007] According to a third aspect of the present invention, there is provided a nozzle guide for mounting a fuel nozzle in a gas turbine engine, comprising a base with an aperture for receiving a nozzle head, and a radial inflow swirler for directing swirled air to a fuel-air mixture discharged from the nozzle.

[0008] Preferred embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is an enlarged sectional view, partly broken away, of a preferred embodiment of a nozzle/guide assembly in accordance with the present invention;
Figure 2 is an elevation view of the nozzle of Figure 1;
Figure 3 is a sectional side view of the nozzle of Figure 2;
Figure 4 is a rear view of the nozzle of Figure 2;
Figure 5 is an enlarged elevation view of the guide of Figure 1;
Figure 6 is a sectional view seen on line 6-6 of Figure 5;
Figure 7 is a sectional side view of the nozzle/guide assembly of Figure 1 mounted in a gas turbine engine combustor;
Figure 8 is a partly diagrammatic sectional side view of an alternate embodiment of the nozzle/guide assembly mounted in a gas turbine engine combustor; and
Figure 9 is a diagram of the angular swirl orientation of the swirlers of the nozzle guide assembly of Figure 8.

[0009] Although specific forms of the present invention have been selected for illustration in the drawings, and the following description is drawn in specific terms for the purpose of describing these forms of the invention, the description is not intended to limit the scope of the invention which is defined in the appended claims.

[0010] Referring initially to Fig. 7, the nozzle/guide assembly of the present invention is generally designated by the numeral 10 and is shown mounted in a combustor 12 which will be described in more detail hereafter. The nozzle/guide assembly 10 generally comprises a nozzle 14 and nozzle guide 16.

[0011] Referring to Figs. 2-4, the nozzle 14 has a head 18 connected to the base 22 by stem 20. The base 22 has a fitting 24 for connection to a fuel source (not shown). A fuel delivery system 26 has a fuel delivery passage 28 terminating in an annular discharge outlet 30 for delivering fuel from the fitting 24 to the discharge outlet 30. The fuel delivery system 26 is the type that delivers a thin film or sheet of fuel at the discharge outlet 30 such as the system described in commonly assigned US Patent No. 4946105 to Pane, Jr. et al. issued August 7, 1990 entitled "Fuel Nozzle For Gas Turbine Engine" (the disclosure of which is incorporated by reference herein) and such system need not be described further for the purposes of the present invention.

[0012] The nozzle head 18 includes an axial inflow swirler 32 and a radial inflow swirler 34. The swirler 32 comprises an air passage 36 concentric to the centreline 38 of the head 18 with an inlet end 44 to receive axially inflowing air, a vane assembly 40 to impart swirl to the air and an outlet end 42 adjoining the fuel discharge outlet 30.

[0013] As best seen in Fig. 1, the radial inflow swirler 34 has an annular air passage 46 concentric to centreline 38 with an outlet end 48 adjoining fuel discharge outlet 30 and an inner end 50. The inner end 50 has a plurality of equispaced, circumferentially disposed air inlet ports 52. The ports 52 open radially outwardly for the radial inflow of air into the passage 46. Each port 52 has an adjoining swirl vane 54 disposed at a predetermined swirl angle to impart swirl to the inflowing air. The angle of the vane determines the amount of swirl imparted to the inflowing air and the vanes 54 may by positioned to provide either clockwise or counterclockwise swirl, i.e., co-swirl or counter-swirl relative to the swirl from swirler 32 depending upon application. (Vane angle is usually measured relative to a perpendicular at the midpoint.) As seen in Fig. 1, the annular passage 46 generally converges radially inwardly as the passage extends longitudinally from the inner end 50 to the outlet end 48.

[0014] The fuel film produced at the fuel discharge outlet is concentric to and disposed between the air outlet 42 of swirler 32 and the air outlet 48 of swirler 34 to subject the fuel film on one side to high velocity air from swirler 32 and on the other side to high velocity air from swirler 34. The high velocity swirling air on each side of the fuel film creates a shear layer which atomizes the fuel and produces a rapidly mixing, downstream flowing fuel-air mixture. The radial inflow swirler is believed to provide more airflow compared to similarly dimensioned axial swirlers and it contributes to reducing vane wakes and providing a more uniform fuel-air mixture with rapid mixing.

[0015] The guide 16 of the present invention is used to mount the nozzle 14 in a combustor end wall (Fig. 7) and properly align the nozzle relative to the combustor as more fully described in commonly assigned US Patent 5463864 to Butler et al. issued 7 November 1995 entitled "Fuel Nozzle Guide For A Gas Turbine Engine Combustor". Referring to Figs. 5 and 6, the guide 16 has a generally annular base 56 with an outwardly extending frustoconical hub section 58 forming a central mounting aperture 60 dimensioned for snug slip-fit mounting of the head 18 (Fig. 1). The centreline of the guide (not shown) is concurrent with the centreline 38 of head 18 when it is mounted within the guide 16.

[0016] The guide 16 includes a radial inflow swirler 62. The swirler 62 has a frustoconical air passage 64 formed in the hub section 58 concentric to centreline 38 (when nozzle head 18 is mounted in the guide 16) with an annular outlet end 66 concentric about and adjacent to outlet 48 of swirler 34 (Fig. 1). The inner end 68 of passage 64 is positioned in the annular base 56 and has a plurality of equispaced, circumferentially disposed air inlet ports 70. The ports 70 open radially outwardly for the radial inflow of air into the passage 64. Each port 70 has an adjoining swirl vane surface 72 disposed at a predetermined swirl angle to impart swirl to the inflowing air. The angle of the vane surface determines the amount of swirl imparted to the inflowing air and the vane surfaces 72 may by positioned to provide either clockwise or counterclockwise swirl, i.e., co-swirl or counter-swirl relative to the swirl from swirlers 32, 34 depending upon application. As seen in Fig. 1, the frustoconical passage 64 generally converges radially inwardly as the passage extends longitudinally from the inner end 68 to the outlet end 66 such that a progressively converging helical air pathway is followed by the swirled air.

[0017] The swirled air from outlet 66 is directed into the fuel-air mixture from the nozzle head 18 producing (above idle power) a fuel rich, more uniform fuel-air mixture with rapid mixing as the mixture moves downstream.

[0018] In the preferred embodiment shown in Figs. 1, 5 and 6, the guide 16 includes an additional air source to the fuel-air mixture in the form of a plurality of axial inflow air passages 74 in a flange portion 76 of base 56. Each passage 74 has an inlet end 78 and an outlet end 80 (Fig. 6) and is disposed generally parallel to passage 64, i.e., extending outwardly from the base and radially inwardly. As best seen in Fig. 5, the outlets 80 are disposed in a concentric array about the outlet 66 of swirler 62. It is believed that air from the outlets 80 purges the area about the nozzle and contributes to the mixing and flow of the fuel-air mixture. Alternately, the passages 74 can be disposed to provide some swirl to the discharged air so as provide an outer curtain or pattern which may tend to confine the rich fuel-air mixture central core downstream.

[0019] Referring to Fig. 7, the embodiment of Fig. 1 is shown mounted in the end wall or dome 82 of combustor 12. In the illustrated embodiment, the vane angle for the swirler 32 is 70 degrees, the vane angle for swirler 34 is 47 degrees and the vane angle for swirler 62 is 22 degrees. The nozzle/guide assembly 10 is positioned to provide a rapidly mixing, highly uniform downstream flowing fuel-air mixture into the combustion chamber 84 which contributes to a low NOx combustion process.

[0020] Referring to Fig. 8 wherein identical numerals are utilized to identify like or similar parts, an alternate embodiment guide 86 is shown having a radial inflow swirler 88 instead of the air passages 74. Similar to swirler 62, the swirler 88 has an annular or frustoconical air passage 90 formed in the hub section 58 concentric about the air passage 64 of swirler 62 with an annular outlet end 92 concentric about and adjacent to outlet 66 of swirler 62. The inner end 94 of passage 90 is positioned in the annular base 56 and has a plurality of equispaced, circumferentially disposed air inlet ports 96. The ports 96 open radially outwardly for the radial inflow of air into the passage 90. Each port 96 has an adjoining swirl vane surface 98 disposed at a predetermined swirl angle to impart swirl to the inflowing air. As previously described the vane angles may be selected as desired and the vane surfaces 72 may by positioned to provide either clockwise or counterclockwise swirl relative to the other swirlers depending upon application.

[0021] Referring to Fig. 9, the swirl orientation for the embodiment of Fig. 8 is shown whereby the swirl direction from swirlers 32, 34 (in the nozzle) is counter to the swirl direction from swirlers 62, 88. In this embodiment, the vane angles of swirlers 32, 34 are unchanged while the vane angle of the swirler 88 is 10 degrees and the vane angle of the swirler 62 is 45 degrees. It is believed that the emanating fuel-air mixture pattern is tighter being confined by the swirled air 100 from the outer swirler 88 as diagrammatically shown (not to scale) in Fig. 8 while the swirled air 102 (counter to the air from swirlers 32, 24) contributes to rapidly mixing the fuel-air mixture to an improved uniform condition for combustion.

[0022] As will be appreciated from the foregoing, a new and improved fuel nozzle and nozzle guide have been described which achieves enhanced atomization, mixing and uniform distribution in the fuel-air mixture so as to contribute to the reduction or control of NOx and other pollutant emissions in a gas turbine engine. The nozzle/guide assembly can produce a rapidly mixed rich fuel-air mixture with the rapid mixing process controlled at some distance downstream of the fuel injection mechanism. Moreover, the described invention is adaptable to varied applications through selective variation of swirler components for control of the mixing process and the fuel-air spray pattern downstream in the combustor.

[0023] Thus it will be seen that, at least in its preferred embodiments, the present invention provides a new and improved fuel injection nozzle and guide assembly which contributes to the reduction or control of NOx emission in a gas turbine engine, an assembly which achieves improved atomization, mixing and uniformity in the fuel-air mixture, an assembly which affords a rapid mixing process controlled at some distance downstream of the fuel injection mechanism, a nozzle and nozzle guide which can produce a rapidly-mixed rich fuel-air mixture, a nozzle and nozzle guide design which is adaptable to varied applications and which facilitates selective variation of components for control of the fuel-air spray pattern downstream in the combustor, such as to achieve a coherent central flow structure downstream from the nozzle, and a nozzle and nozzle guide assemble which is dimensionally compact for a given airflow and durable in use.

[0024] As will be apparent to persons skilled in the art, various modifications and adaptations of the structure above-described will become readily apparent without departure from the scope of the invention, as defined in the appended claims.

Claims

1. A fuel injection nozzle/guide assembly (10) for a gas turbine engine comprising:

   a fuel delivery passage (28) having a discharge outlet (30) for discharging fuel;
   a first air flow swirler (32) having a first outlet (42) disposed to provide swirling air to discharging fuel, said first swirler (32) being an axial inflow swirler;
   a second air flow swirler (34) having a second outlet (48) disposed to provide swirling air to discharging fuel, said second swirler (34) being a radial inflow swirler;
   said first and second outlets (42, 48) being positioned to provide swirling air to fuel at said discharge outlet (30) to produce a downstream-flowing fuel air mixture;
   a third air flow swirler (62) having a third outlet (66) disposed to provide swirling air to said fuel air mixture, said third swirler (62) being a radial inflow swirler.

2. An assembly as claimed in claim 1, wherein said first air swirler (32) is configured to swirl air in a first angular direction, and said second air swirler (34) is configured to swirl air in said first angular direction.

3. An assembly as claimed in claim 2, wherein said third air swirler (62) is configured to swirl air in said first angular direction.

4. An assembly as claimed in claim 3, further comprising a fourth air flow swirler (88) having a fourth outlet (92) disposed to provide swirling air to said fuel air mixture, said fourth swirler (88) being a radial inflow swirler with said fourth outlet (92) disposed about said third outlet (66) of said third swirler (62) and configured to swirl air in said first angular direction.

5. An assembly as claimed in claim 2, wherein said third air swirler (62) is configured to swirl air in a second angular direction opposite to said first angular direction.

6. An assembly as claimed in claim 5, further comprising a fourth air flow swirler (88) having a fourth outlet (92) disposed to provide swirling air to said fuel air mixture, said fourth swirler (88) being a radial inflow swirler with said fourth outlet (92) disposed about said third outlet (66) of said third swirler (62) and configured to swirl air in said second angular direction.

7. An assembly as claimed in claim 5, further comprising a fourth air flow swirler (88) having a fourth out-

let (92) disposed to provide swirling air to said fuel air mixture, said fourth swirler (88) being a radial inflow swirler with said fourth outlet (92) disposed about said third outlet (66) of said third swirler (62) and configured to swirl air in said first angular direction.

8. An assembly as claimed in claim 3 or claim 5, further comprising an array of air passages (74) about said third outlet (66) of said third swirler (62), said fuel-air mixture having a centreline and said array of air passages (74) configured to discharge air approximately parallel to said centreline.

9. An assembly as claimed in claim 1, further comprising:

a nozzle guide (16) configured for mounting in the end wall of a combustion chamber and having an aperture (60) for receiving a nozzle (14), said nozzle guide (16) containing said third air flow swirler (62); and
a nozzle (14) containing said fuel delivery passage (28) and being configured for mounting in said aperture (60) of said nozzle guide (16).

10. An assembly as claimed in claim 9, wherein said nozzle (14) contains said first and second air flow swirlers (32, 34).

11. An assembly as claimed in claim 10, wherein said nozzle guide (16) contains a fourth air flow swirler (88) having a fourth outlet (92) disposed to provide swirling air to said fuel air mixture, said fourth swirler (88) being a radial inflow swirler with said fourth outlet (92) disposed about said third outlet (66) of said third swirler (62).

12. An assembly as claimed in claim 10 or claim 11, wherein said nozzle guide (16) contains an array of air passages (74) about said third outlet (66) of said third swirler (62), said fuel-air mixture having a centreline and said array of air passages (74) configured to discharge air approximately parallel to said centreline.

13. An assembly as claimed in any of claims 9 to 12, wherein said first air swirler (32) comprises a central air passageway (36) in said nozzle (14) and a first air-swirling vane (40) subassembly mounted therein, said air passageway (36) having inner and outer ends and a longitudinal axis defining a nozzle centreline with said first outlet (42) disposed at said outer end and concentric to said centreline, said discharge outlet (30) of said fuel delivery passage being concentric to said centreline and positioned axially outwardly adjacent to said first outlet (42); and said second air swirler (34) comprises an annular air passage (46) in said nozzle concentric to said centreline with inner and outer ends, said inner end having a plurality of radial inlet ports (52) for the inflow of air with an air-swirling vane (54) adjoining each said inlet port and said second outlet (48) being disposed at said outer end concentric to said centreline and positioned axially outwardly adjacent to said discharge outlet (30).

14. An assembly as claimed in claim 13, wherein said third air swirler (62) comprises an annular air passage (64) in said nozzle guide (16) concentric to said nozzle centreline with inner and outer ends, said inner end having a plurality of radial inlet ports (70) for the inflow of air with an air-swirling vane (72) adjoining each said inlet port and said third outlet (66) being disposed at said outer end concentric to said centreline and positioned axially outwardly adjacent to said second outlet (48) of said second air swirler (34).

15. An assembly as claimed in any preceding claim, wherein said discharge outlet (30) is configured to discharge fuel as an annular film, said first outlet (42) of said first air flow swirler (32) is positioned to provide swirling air to one side of said annular film, said second outlet (48) of said second air flow swirler (34) is positioned to provide swirling air to the other side of said annular sheet so as to atomise said fuel by shear forces between the swirled air from said first and second air flow swirlers (32, 34).

16. A fuel nozzle for a gas turbine engine comprising:

a base (22) adapted for connection to a source of fuel;
a nozzle head (18) having a longitudinal axis;
a fuel delivery passage (28) extending from said base (22) to said head (18) and having a discharge outlet (30) for discharging fuel;
an axial inflow swirler (32) in said nozzle head (18) having an axially aligned inlet to receive axial inflow air, a vane assembly (40) to impart swirl to air flowing therethrough, and an outlet (42) disposed to direct the swirled air to fuel at the discharge outlet; and
a radial inflow swirler (34) comprising an annular air passage (46) formed in said nozzle head (18) concentric to said axis with inner and outer ends, a plurality of inlet ports (52) circumferentially disposed on said nozzle head (18) and opening radially outwardly for the radial inflow of air into the inner end of said annular passage (46) with an air-swirling vane (54) adjoining each said inlet port, and an outlet (48) at said outer end concentric to said axis and disposed to direct swirled air therefrom to fuel at the discharge outlet (30).

17. A nozzle guide for mounting a fuel nozzle in a gas turbine engine comprising:

a base (56) having an aperture (60) for receiving the nozzle head (18) of a fuel nozzle (14), said aperture having a centre axis; and
a radial inflow swirler (62) comprising a first annular air passage (64) formed in said base (56) concentric to said centre axis with inner and outer ends, a plurality of inlet ports (70) circumferentially disposed on said base (56) and opening radially outwardly from said centre axis for the radial inflow of air into the inner end of said first annular passage (64), an air-swirling vane (72) adjoining each said inlet port (70) to impart swirl to air flowing therethrough, and an outlet (66) at said outer end of said first annular passage (64) concentric to said centre axis and disposed to direct swirled air therefrom to a fuel-air mixture discharged from a nozzle (14) mounted within said aperture (60).

18. A device as claimed in claim 17, further comprising a second radial inflow swirler (88) having a second outlet (92) disposed to direct swirled air therefrom to a fuel-air mixture discharged from a nozzle (14) mounted within said aperture (60), said swirler (88) comprising a second annular air passage (90) formed in said base about said first annular passage (64) concentric to said centre axis with inner and outer ends, a plurality of inlet ports (96) circumferentially disposed on said base (56) and opening radially outwardly from said centre axis for the radial inflow of air into the inner end of said second annular passage (90), an air-swirling vane (98) adjoining each said inlet port (96) to impart swirl to air flowing therethrough, and an outlet (92) at said outer end of said second annular passage (90) concentric to said centre axis and disposed to direct swirled air therefrom to a fuel-air mixture discharged from a nozzle (14) mounted within said aperture (60).

19. A device as claimed in claim 17 or claim 18, further comprising an array of air passages (74) about said first annular passage (64), each said air passage extending generally axially relative to said centre axis and having an inner inlet end (78) opening axially to receive axial inflow air and an outer outlet end (80) disposed to direct air therefrom to a fuel-air mixture discharged from a nozzle (14) mounted within said aperture (60).

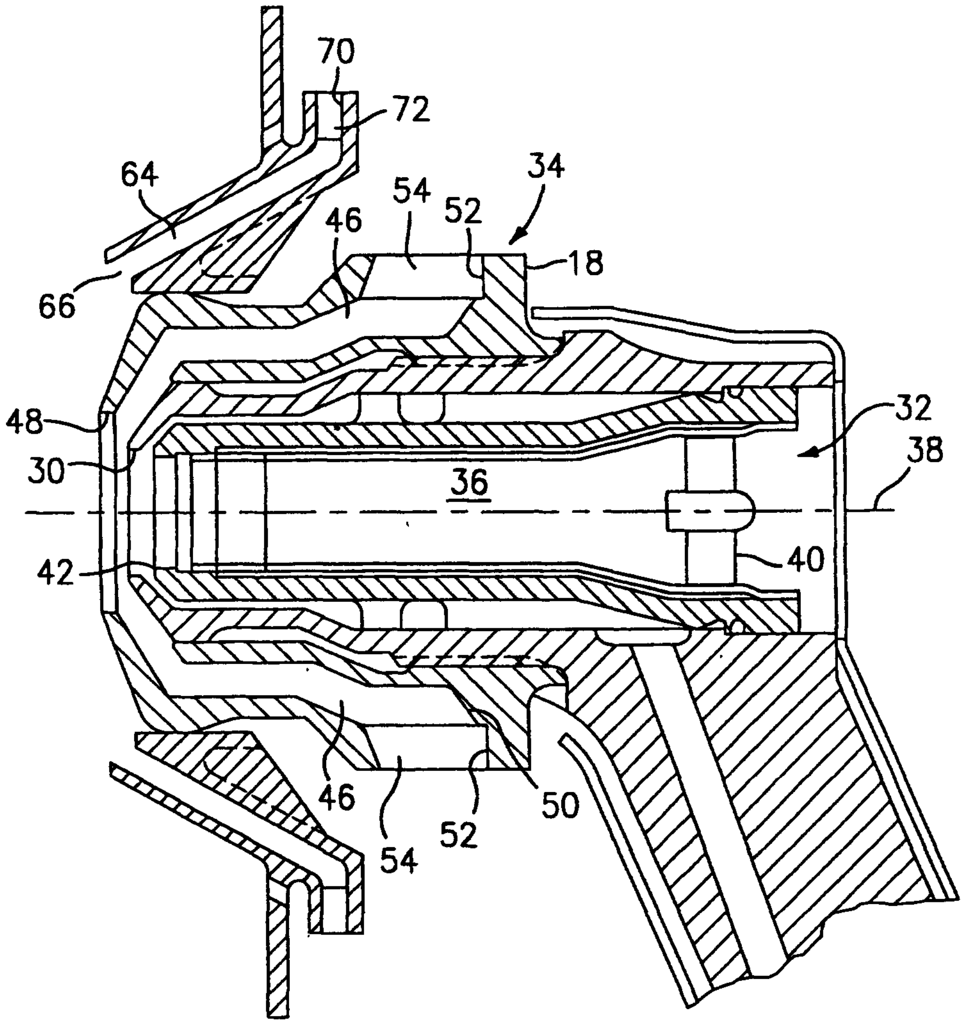

FIG. 1

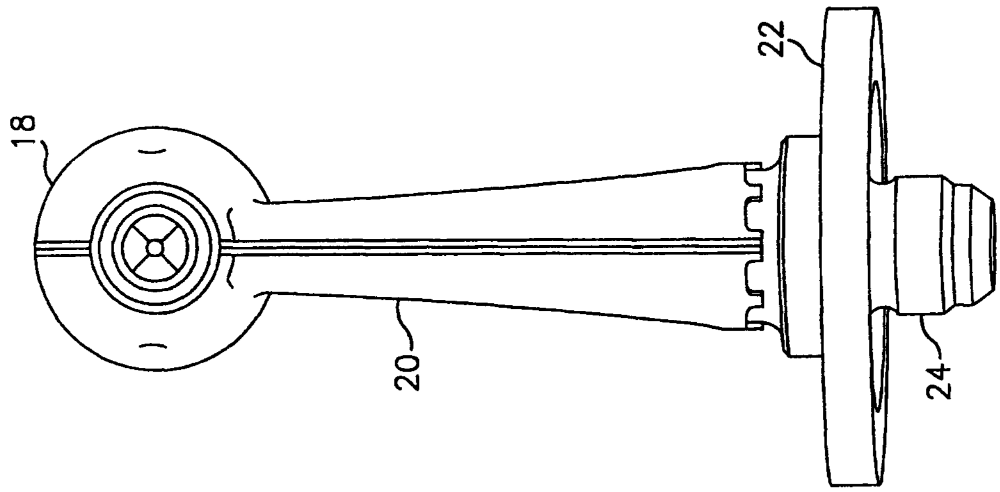

FIG. 4

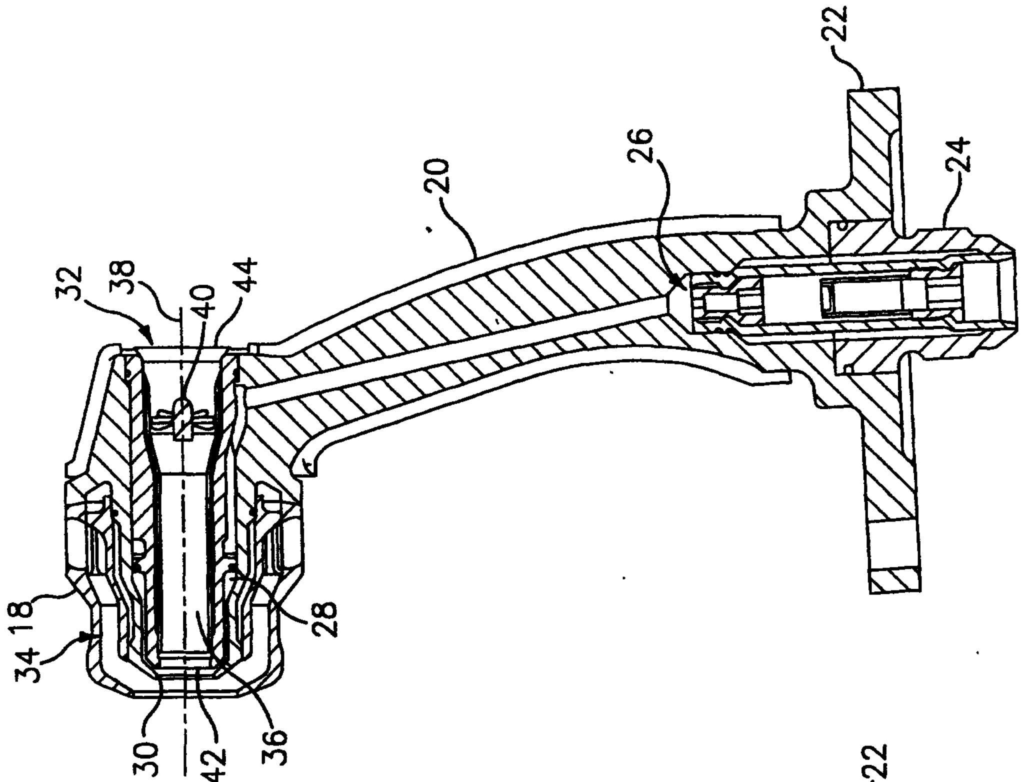

FIG. 3

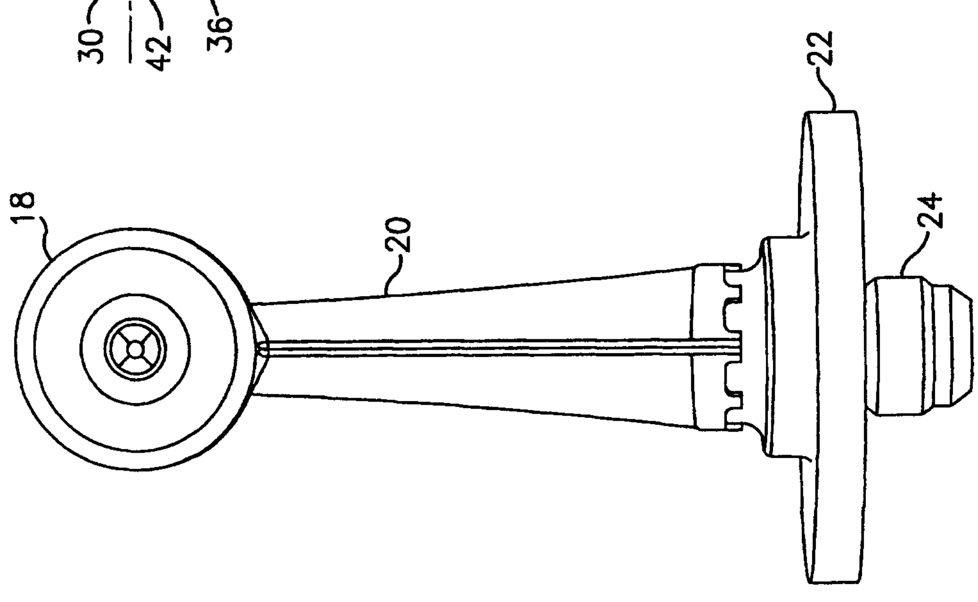

FIG. 2

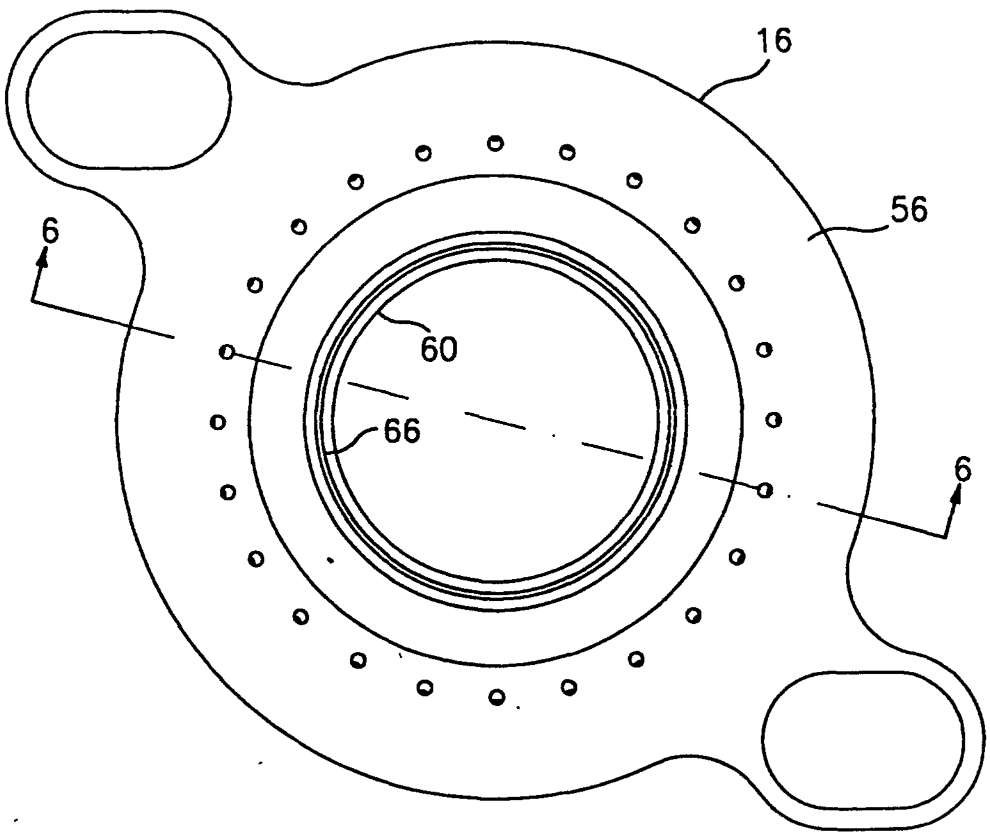

FIG. 5

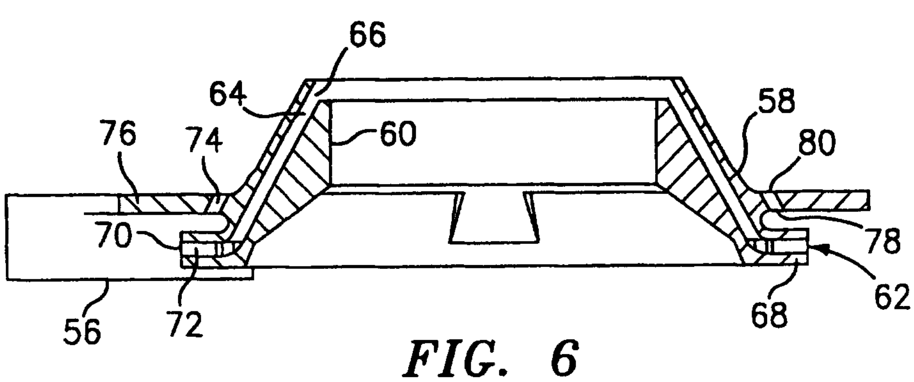

FIG. 6

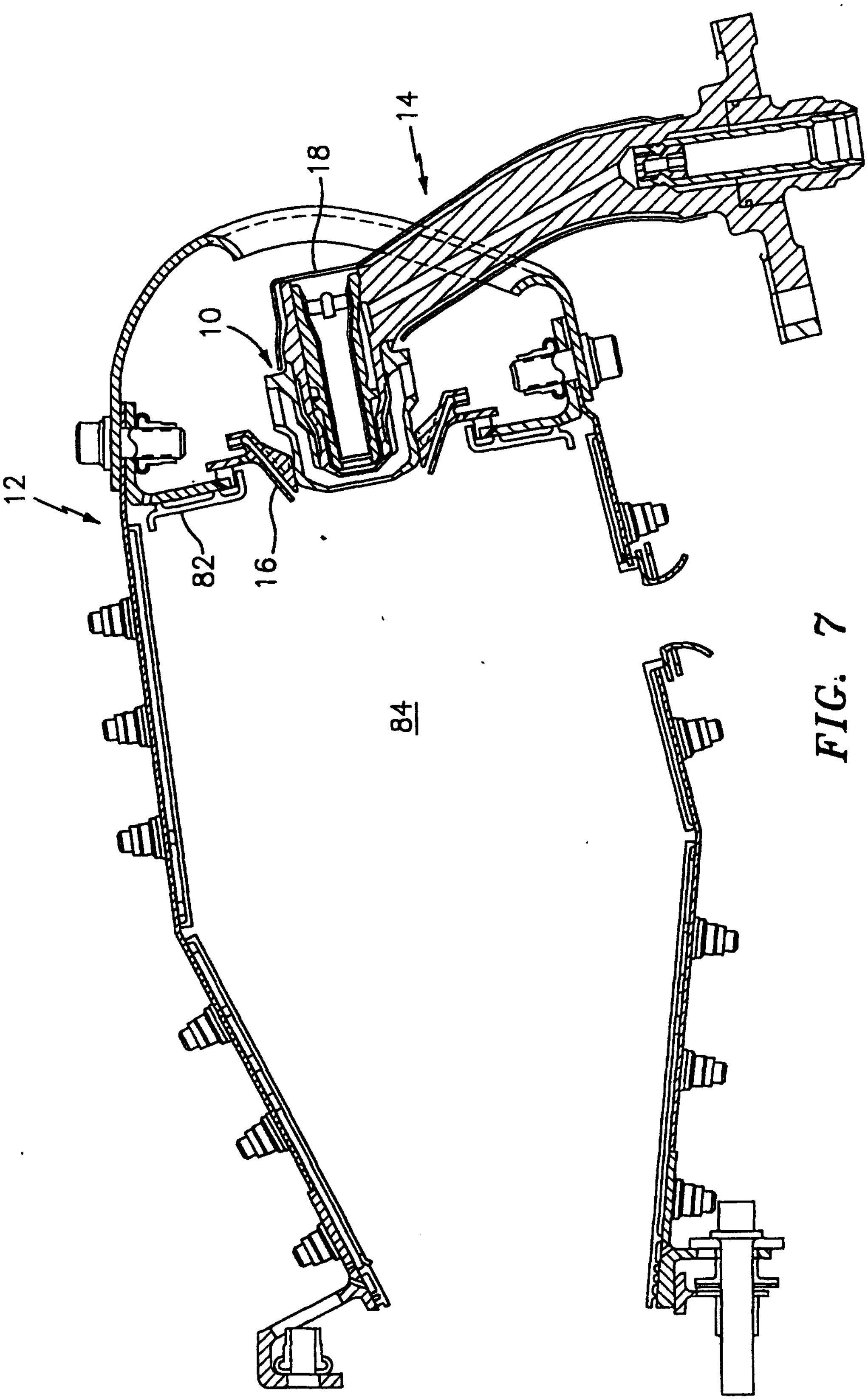

FIG. 7

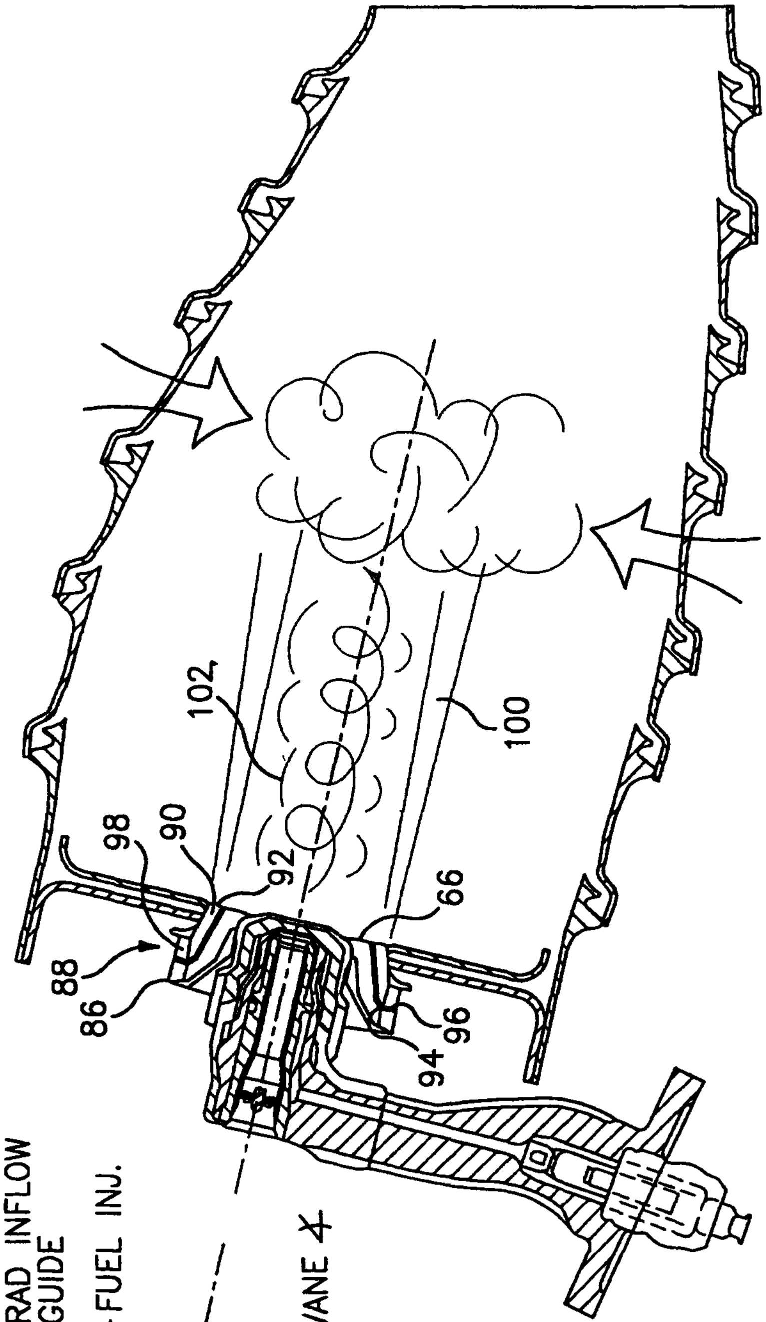
102
100
98
90
92
66
88
86
94
96

FIG. 8

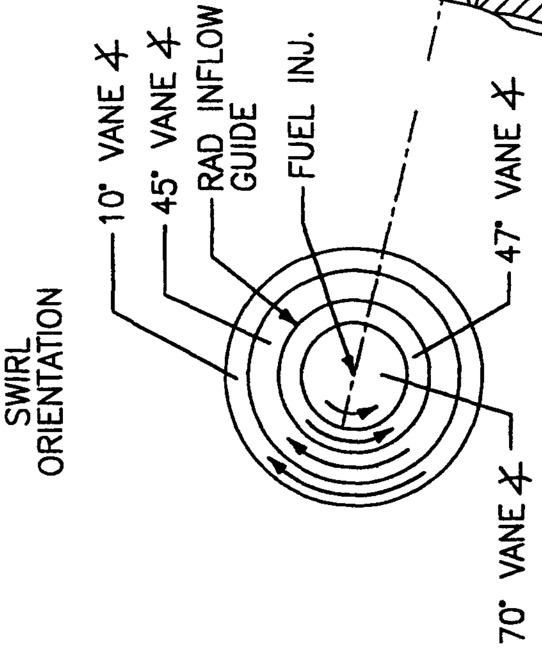
SWIRL ORIENTATION
10° VANE ∡
45° VANE ∡
RAD INFLOW GUIDE
FUEL INJ.
47° VANE ∡
70° VANE ∡

FIG. 9