United States Patent [19]

Vdoviak

[11] **3,834,159**

[45] **Sept. 10, 1974**

[54] **COMBUSTION APPARATUS**

[75] Inventor: **John William Vdoviak,** Marblehead, Mass.

[73] Assignee: **General Electric Company,** Lynn, Mass.

[22] Filed: **Aug. 3, 1973**

[21] Appl. No.: **385,420**

[52] **U.S. Cl.**..... **60/39.65,** 60/39.74 R, 239/403

[51] **Int. Cl.**..... **F02c 3/00,** F02c 7/22

[58] **Field of Search**..... 60/39.74 R, 39.74 B, 39.71, 60/39.65; 239/403–406

[56] **References Cited**

UNITED STATES PATENTS

3,000,183	9/1961	Hall	60/39.65
3,373,562	3/1968	Wormser	60/39.65 X
3,512,359	5/1970	Pierce	60/39.74 R
3,605,405	9/1971	DuBell et al.	60/39.74 R
3,703,259	11/1972	Sturgess et al.	60/34.74 R

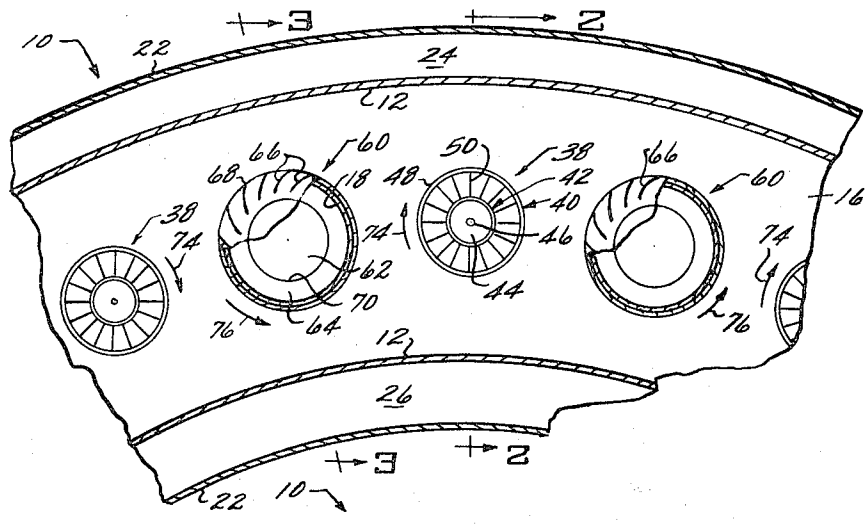
Primary Examiner—C. J. Husar

Assistant Examiner—Robert E. Garrett

[57] **ABSTRACT**

A combustion apparatus is provided for a gas turbine engine wherein a plurality of fuel carbureting air swirlers are alternately spaced between a plurality of stabilizing air swirlers in order that fuel may be readily dispersed and atomized for efficient combustion within the chamber without precipitating excessive exhaust smoke and without jeopardizing flameholding stability within the combustion chamber.

8 Claims, 4 Drawing Figures



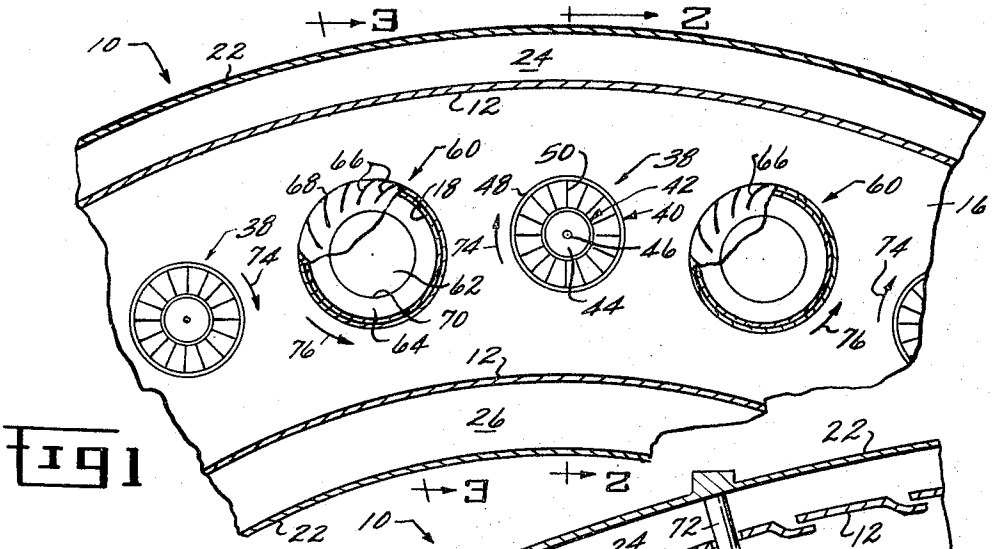


FIG 1

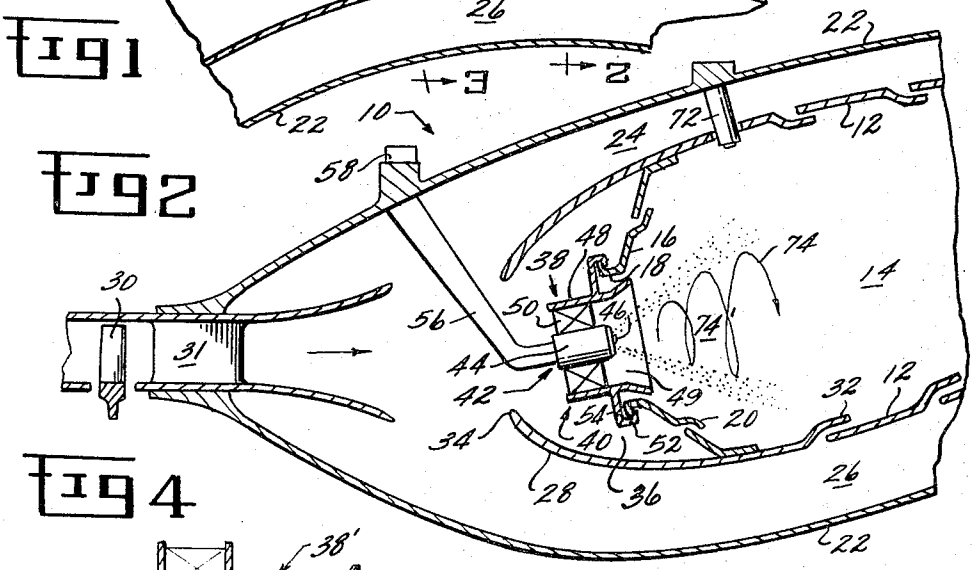


FIG 2

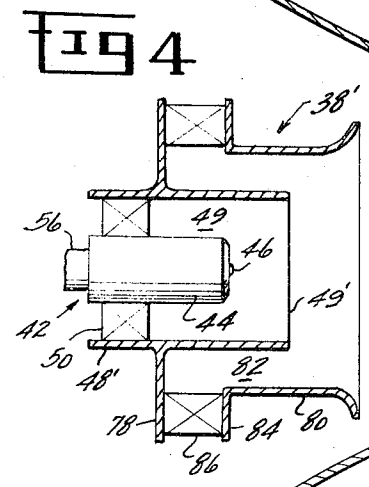


FIG 4

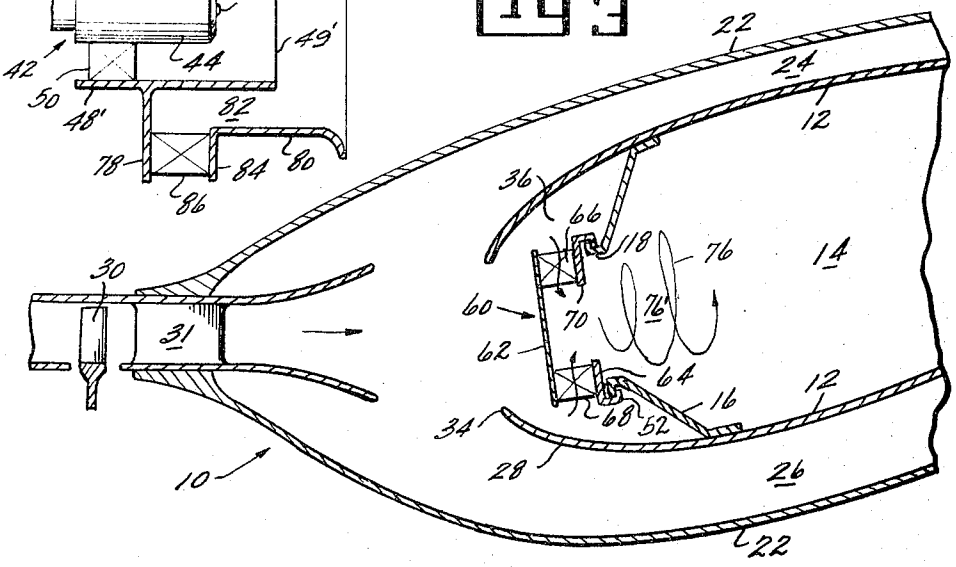


FIG 3

COMBUSTION APPARATUS

BACKGROUND OF THE INVENTION

This invention generally relates to a combustion apparatus and, more particularly, to a combustion apparatus of the type suitable for a gas turbine engine employing a system of alternately spaced fuel carbureting air swirlers and stabilizing air swirlers which cooperatively provide efficient combustion together with improved flameholding stability.

Fuel injection into a continuous burning combustion chamber as, for example, in a gas turbine engine has posed continuing design problems. Difficulties have been encountered in injecting fuel in a highly dispersed manner so as to achieve complete and efficient combustion of the fuel, and at the same time minimize the occurrence of fuel-rich pockets which upon combustion produce carbon, smoke, or unburned hydrocarbon pollutants. Fuel injection difficulties have been further complicated by the recent introduction of gas turbine engines having increased combustor pressure levels. Existing fuel spray atomizer efficiency decreases as combustor pressure is increased, resulting in a more non-uniform dispersion of fuel, together with an increase in the fuel-rich zones within the combustion chamber which cause reduced burner efficiency, excessive exhaust smoke, and a non-uniform heating of the combustor shell, a condition commonly referred to as hot streaking, which can lead to rapid deterioration of the shell.

High fuel pressure spray atomizers have not proved entirely satisfactory because of the present limitations on fuel pump pressure. Systems for vaporizing fuel upon injection into the combustor have also proved to be severely limited due to the dependence of the vaporization process on the temperature of the fuel and air entering the combustor.

Recently suggested low pressure fuel carbureting air swirlers which may be of a type disclosed in U.S. Pat. No. 3,703,259 to the instant assignee, have proved highly successful in overcoming many of the aforementioned difficulties. Low pressure fuel carbureting air swirlers generally include at least one air swirler for generating a vortical flow within the combustion chamber whereby fuel droplets discharged by a fuel injector are entrained within the swirler vortical flow and atomized thereby. Continuous ignition and flame stability within the combustion chamber are generally maintained by the axial recirculation of the hot products of combustion within the core of each vortical flow which is at a reduced pressure. In order to provide for efficient and uniform atomization of the fuel droplets, the inlet airflow, particularly through the air swirlers, may be maximized by such techniques as the use of an axial flow type of air swirler. Maximizing the inlet airflow for efficient and uniform atomization, however, has the adverse effect of reducing the strength of the vortical flow resulting in a reduced pressure at the core of each vortex with a corresponding reduction in the degree of recirculation of the hot products of combustion within the core. The net effect may be a reduction in the overall flameholding stability within the combustion chamber resulting in a loud rumble from the engine or even a flame blowout.

Therefore, it is a primary object of this invention to provide a combustion apparatus for a gas turbine engine wherein fuel may be readily dispersed and atomized for efficient combustion without generating excessive exhaust smoke and without jeopardizing flameholding stability within the combustion chamber.

It is another object of this invention to provide a combustion apparatus of the high pressure type for a gas turbine engine wherein low pressure fuel carbureting air swirlers may be utilized for efficient atomization and combustion without generating excessive exhaust smoke and without incurring undue flameholding instability.

It is a further object of this invention to provide a combustion apparatus of the high pressure type for a gas turbine engine wherein improved flameholding stability may be provided by alternately spacing stabilizing air swirlers with fuel carbureting air swirlers.

SUMMARY OF THE INVENTION

Briefly stated, the above and other related objects are attained by providing a combustion apparatus having a liner which defines a combustion chamber therein. The combustion chamber includes a plurality of fuel carbureting air swirlers disposed therein in spaced apart relation wherein each fuel carbureting air swirler includes fuel injection means for receiving and dispersing an inlet flow of fuel together with swirl means for imparting a circumferential velocity component to an inlet airflow. The inlet airflow is then discharged into the combustion chamber in a primary vortical airflow which entrains and generally atomizes the fuel emanating from the fuel injector. A plurality of stabilizing air swirlers are alternately spaced apart between the fuel carbureting air swirlers. Each stabilizing air swirler imparts a circumferential velocity component to an inlet airflow so as to discharge into the combustion chamber a secondary vortical airflow of greater strength than the primary vortical airflow thereby entraining a portion of the hot products of combustion and causing a recirculation thereof so as to provide generally continuous reignition together with flameholding stability.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be better understood upon reading the following description of the preferred embodiments in conjunction with the accompanying drawings.

FIG. 1 shows a cross-sectional view of a portion of the combustion apparatus of this invention.

FIG. 2 shows a cross-sectional view taken along the line 2—2 of FIG. 1.

FIG. 3 shows a cross-sectional view taken along the line 3—3 of FIG. 1.

FIG. 4 shows a cross-sectional view of an alternate embodiment for the fuel carbureting air swirler of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and particularly to FIGS. 1, 2 and 3, a continuous burning combustion apparatus of the type suitable for use in a gas turbine engine has been shown generally at 10 as comprising a hollow liner 12 defining a combustion chamber 14 therein. The hollow body 12 includes a domed upstream transverse closure member 16 having a plurality of circumferentially spaced apart openings 18 therein. The openings 18 alternately receive fuel carbureting air

swirlers **38** and stabilizing air swirlers **60** as will become apparent from the following discussion. The domed closure member **16** may also include a plurality of spaced apart apertures or louvers **20** for the admission of secondary airflow and for cooling purposes. The upstream end of the chamber **14** is defined by the domed upstream closure member **16** together with the fuel carbureting air swirlers **38** and stabilizing air swirlers **60** wherein the domed member **16** is suitably secured to the hollow liner **12.** As will be understood by those skilled in the art, the combustion chamber **14** may be of the annular type or the cannular type.

An outer shell **22** may be provided to enclose the hollow liner **12** and define outer and inner air passages **24** and **26** respectively in cooperation with the hollow body **12.** As will be understood, the passages **24** and **26** are adapted to deliver a flow of pressurized air from a suitable source, such as a compressor **30** into the combustion chamber **14** through suitable apertures or louvers **32** for cooling of the hollow liner **12** and dilution of the gaseous products of combustion as is well known in the art. The compressed airflow exiting from the compressor **30** discharges through a plurality of circumferentially spaced apart outlet guide vanes **31.**

An upstream extension **28** is provided for the hollow liner **12** and is adapted to function as a flow splitter to divide the pressurized air delivered from the compressor **30** between passages **24, 26** and an upstream end opening **34** of the extension **28.** The opening **34** communicates with a chamber **36** which is defined internally of the extension **28** and the domed member **16.**

Referring now particularly to FIG. **2** in conjunction with FIG. **1,** it may be seen that the alternately spaced fuel carbureting air swirlers **38** each include a swirl cup **40** which is preferably of the axial flow type. A fuel injector **42,** which may be of a conventional atomizing type having a spray nozzle **46,** is housed within a centerbody **44** which is centrally disposed within the swirl cup **40.** The swirl cup **40** includes an outer shroud member **48** spaced apart from the centerbody **44** so as to define a substantially annular air passage **49** therebetween. A plurality of circumferentially spaced apart axial swirl vanes **50** are disposed between the centerbody **44** and the outer shroud member **48,** and receive a portion of the compressor discharge airflow, imparting a strong circumferential swirl component thereto in a clockwise direction as viewed from the aft end of the combustion chamber **14.**

The fuel carbureting air swirler **38** may be retained relative to the domed upstream closure member **16** by a floating ferrule **52** which accommodates both circumferential and radial thermal growth. The floating ferrule **52** may be attached to or formed integrally to a radially extending circumferential wall member **54,** the inner periphery of which is joined to the outer shroud member **48.** The floating ferrule **52** is provided in order to maintain the concentricity of the outer shroud member **48** with respect to the centerbody **44** upon thermal expansion.

The centerbody **44** may be integrally formed with a hollow stem **56** which is retained in position by connection to the outer shell **22** at a fitting **58.** The hollow stem **56** includes a suitable fuel delivery means which extends through the outer shell **22** and communicates with a source of pressurized fuel, not shown, so as to provide fuel to the spray nozzle **46.**

Alternately spaced between the fuel carbureting air swirlers **38** are the stabilizing air swirlers **60** which may be generally of a radial flow type. Referring now particularly to FIG. **3,** in conjunction with FIG. **1,** the stabilizing air swirler **60** is shown as including a radially extending wall member **62** spaced axially forward of a second radially extending annular wall member **64.** Disposed intermediate the forward and aft wall members **62, 64** are a plurality of circumferentially spaced apart radial swirl vanes **66** which receive an inlet flow of compressor discharge air through an axially extending annular inlet **68,** defined by the outer peripheral edges of the forward and aft wall members. The swirl vanes **66** receive compressor discharge air and are shown as imparting a strong circumferential swirl component to the airflow in a counter-clockwise direction as viewed from the aft end of the combustion chamber **14.** The swirled airflow is then discharged from the stabilizing air swirler **60** through a radially extending circular outlet **70** defined by the inner periphery of the annular wall member **64.**

As will be understood by those skilled in the art, suitable ignition means **72** such as an electrical spark are included within the combustion chamber **14** to provide initial ignition of the combustible fuel-air mixture discharged by the fuel carburetors **38.**

In operation, relatively low pressure liquid fuel is delivered to the fuel carbureting air swirler **38** through the hollow stem **56,** whereupon the fuel is introduced into the combustion chamber **14** by the fuel injector **42.** The circumferentially spaced apart swirl vanes **50** receive compressor discharge air and impart a circumferential velocity component thereto so as to discharge a vortical flow **74.** The vortical flow **74** entrains the fuel droplets emanating from the fuel injector **42** whereupon the fuel droplets are atomized and uniformly distributed to provide a lean mixture with a high air to fuel ratio. As is readily apparent, the high air to fuel ratio provides for efficient combustion and reduces the overall amount of smoke emitted from the exhaust of the gas turbine engine.

The electrical spark from the ignition means **72** is generally not continuous and provides only for the initial ignition of the fuel-air mixture. Continuous reignition within the combustion chamber **14** is thereafter maintained by the action of the vortical flow **74,** the core of which, shown generally at **74'**, is at a reduced pressure and thereby entrains a portion of the hot products of combustion so as to cause a recirculation thereof. It is this recirculation of the hot products of combustion within the core of the vortical flow **74** which ultimately determines the flame stability e.g., if the pressure of the core **74'** is not sufficiently reduced, there will be an inadequate recirculation of the hot products of combustion therein resulting in flame instability and possibly even a flame blowout. The pressure of the core **74'** of the vortical flow **74,** however, generally depends upon the ratio of the tangential velocity component to the axial velocity component of the vortical flow. If the tangential velocity component of the vortical flow can be increased relative to its axial velocity component, there will be a reduction in the pressure within the core of the vortical flow thereby increasing the recirculation of the products of combustion within the core.

The axial flow configuration of the swirl cup **40** is arranged to provide a maximum inlet airflow of compres-

sor discharge air to the combustion chamber **14** so as to provide a highly atomized and lean fuel-air mixture which burns efficiently without substantial smoke emissions. The increased airflow through the axial swirlers, however, provides for a weakened vortical flow where the ratio of the tangential velocity component to the axial velocity component is low with a corresponding increase in the core pressure within the vortical flow. The relatively high core pressure of the vortical flow **74** reduces the amount of recirculation of hot products of combustion, thereby reducing the flame holding stability within the combustion chamber **14** and increasing the risk of unstable combustion (i.e., rumble) or an actual flame blowout.

Referring now to the alternately spaced stabilizing air swirlers **60,** it can be seen that the radial flow arrangement of the swirl vanes **66** provides for a vortical flow **76** wherein the ratio of the tangential velocity component to the axial velocity component may be substantially increased in comparison with that of the vortical flow **74.** Because the compressor discharge air must turn a minimum angle of 90° and approach a near radial direction before entering the annular inlet **68,** there is a substantial decrease in the axial velocity component of the vortical airflow emanating from the stabilizing air swirler **60.** The reduced axial velocity component provides for an increased ratio of tangential to axial velocity components, thereby reducing the overall pressure within the vortical core shown generally at **76'**. The reduced pressure of the core **76'** provides an area wherein the hot products of combustion may be recirculated to provide continuous heat energy to the fuel-air mixture for reignition thereof, thereby substantially improving flame holding stability within the combustion chamber **14.**

The arrangement of this invention which provides for alternately spacing fuel carbureting air swirlers with stabilizing air swirlers accomplished both efficient atomization and burning without risk of flame instability or blowout. Referring again to FIG. **1,** there is shown an arrangement whereby the axial and radial flow swirlers provide vortical airflows **74, 76** in opposing circumferential directions, such that the airflow directions at the interfaces between adjacent vortices are identical and thereby augment each other to increase overall flameholding stability. Alternatively, the radial and axial flow swirlers could be arranged to provide vortical airflows **74, 76** in the same circumferential directions in which case the airflow directions at the interfaces between the vortical flows would be opposed, thereby increasing the shear forces which operate on the fuel droplets so as to increase the degree of atomization with a corresponding reduction in overall flameholding stability.

It should be readily appreciated by those skilled in the art that the scope of invention is by no means limited to the type of fuel carbureting air swirler herein depicted, and may also include other types of fuel carbureting air swirlers which are generally of the low pressure type such as is shown in FIG. **4,** where like numerals refer to previously described elements. The fuel carbureting air swirler shown generally at **38'** includes a secondary shroud member **80** spaced apart from a primary shroud member **48'** so as to define an annular passage **82** therebetween. A plurality of circumferentially spaced apart radial flow swirl vanes **86** are disposed between a forward radially extending circumferential wall member **78** formed integral to the primary shroud **48'** and an aft radially extending circumferential wall member **84** formed integral to the secondary shroud **80.**

In operation, a portion of the liquid fuel emanating from the fuel injector **42** is deposited on the interior circumferential surface of the primary shroud member **48'**. That portion of the fuel so deposited is centrifugally driven or pushed down the interior surface of the primary shroud member towards a downstream circumferential transverse lip **49'**. The vortical airflow emanating from the radial flow vanes **86** is in a circumferential direction opposing that of the vortical airflow from the axial flow vanes **50.** In this manner, a conical area of turbulent airflow is established on the boundary between the counter-rotating vortical flows and fuel reaching the primary shroud lip **49'** becomes highly atomized by the high aerodynamic shear stresses developed at the confluence of the counter-rotating vortices. The atomized fuel droplets then become highly dispersed by the turbulent airflow at the boundary between the counter-rotating vortical airflows.

Although the fuel carbureting air swirler **38'** utilizes a plurality of radial flow swirl vanes, it nevertheless incurs the same disadvantages previously described in relation to the fuel carbureting air swirler of FIG. **2.** The reason being that the counter-rotating air streams interact and dilute the overall strength of the vortical flow such that the pressure at the core is increased so as to reduce the recirculation of the products of combustion and thus reduce flame holding stability.

Although the fuel carbureting air swirlers and stabilizing air swirlers have been depicted in general terms of radial and axial flow air swirlers, it should be readily appreciated that the scope of invention is by no means so limited, and that in fact other means of swirling may be employed so long as the stabilizing air swirlers generate a stronger vortical airflow than the fuel carbureting air swirlers. What is generally understood to be the stronger vortical flow is that vortex which has the greater ratio of tangential velocity component to axial velocity component. Thus it will be appreciated by those skilled in the art that although various embodiments for the present invention have been depicted and described, many modifications, substitutions and changes may be made thereto without departing from the invention's fundamental theme.

What is claimed is:

1. A combustion apparatus comprising:

liner means defining a combustion chamber therein;

a plurality of fuel carbureting air swirlers disposed in spaced apart relation about the combustion chamber wherein each carbureting air swirler includes fuel injection means for receiving and dispersing an inlet flow of fuel together with swirl means for imparting a circumferential velocity component to an inlet airflow so as to discharge into the combustion chamber a first vortical airflow which entrains, mixes and generally atomizes the fuel emanating from the fuel injector;

and a plurality of stabilizing air swirlers alternately spaced apart between the fuel carbureting air swirlers wherein each stabilizing air swirler imparts a circumferential velocity component to an inlet airflow so as to discharge into the combustion chamber a second vortical airflow of greater strength

than the first vortical airflow thereby entraining a portion of the hot products of combustion and causing a recirculation thereof so as to provide generally continuous reignition.

2. The combustion apparatus of claim **1** wherein:
the liner means defines a hollow annular combustion chamber therein, and the upstream end of the combustion chamber is defined by a transverse closure member having a plurality of circumferentially spaced apart openings therein which alternately receive the fuel carbureting air swirlers and stabilizing air swirlers.

3. The combustion apparatus of claim **2** wherein:
the fuel carbureting swirl means includes a swirl cup of the axial inflow type, the fuel injector is housed within a centerbody centrally disposed within the swirl cup, and the stabilizing air swirlers are of the radial flow type such that the core portions of the second vortical airflows are generally at a lower pressure than the core portions of the first vortical flows, providing improved flame holding stability within the combustion chamber.

4. The combustion apparatus of claim **3** wherein:
the swirl cup includes an outer shroud member spaced apart from the centerbody so as to define a substantially annular air passage therebetween together with a plurality of circumferentially spaced apart axial swirl vanes disposed between the centerbody and the outer shroud member; and
the stabilizing air swirler includes a first generally radially extending wall member spaced axially forward of a second radially extending annular wall member together with a plurality of circumferentially spaced apart radial swirl vanes disposed intermediate the first and second wall member so as to receive an inlet airflow through an axially extending annular inlet defined by the outer peripheral edges of the first and second wall members.

5. The combustion apparatus of claim **3** wherein:
the swirl cup includes a primary shroud spaced apart from the centerbody so as to define a first substantially annular air passage therebetween together with a plurality of circumferentially spaced apart axial swirl vanes disposed between the centerbody and the primary shroud and further including a secondary shroud member spaced apart from the primary shroud so as to define a second annular air passage therebetween together with a plurality of circumferentially spaced apart radial flow swirl vanes disposed intermediate a first radially extending circumferential wall member integrally joined to the primary shroud and a second radially extending circumferential wall member integrally joined to the secondary shroud; and
the stabilizing air swirler includes a third generally radially extending wall member spaced axially forward of a fourth radially extending annular wall member together with a plurality of circumferentially spaced apart radial swirl vanes disposed intermediate the third and fourth wall members so as to receive an inlet airflow through an axially extending annular inlet defined by the outer peripheral edges of the first and second wall members.

6. A combustion apparatus comprising:
means for delivering a compressed inlet airflow;
a hollow liner defining an annular combustion chamber therein and open at one end to receive a portion of the compressed inlet airflow;
an outer shell enclosing the hollow liner and spaced apart therefrom so as to define inner and outer air passages for directing a portion of the compressed inlet airflow into the combustion chamber through a plurality of openings in the liner;
a plurality of fuel carbureting air swirlers disposed in spaced apart relation about the combustion chamber wherein each carburetor includes fuel injection means for receiving and dispersing an inlet flow of fuel together with swirl means for imparting a circumferential velocity component to the compressed inlet airflow so as to discharge into the combustion chamber a first vortical air-flow which entrains and generally atomizes the fuel emanating from the fuel injector;
and a plurality of stabilizing air swirlers alternately spaced apart between the fuel carbureting air swirlers wherein each stabilizing air swirler imparts a circumferential velocity component to the compressed inlet airflow so as to discharge into the combustion chamber a second vortical airflow of greater strength than the first vortical airflow thereby entraining a portion of the hot products of combustion and causing a recirculation thereof so as to provide continuous reignition.

7. The combustion apparatus of claim **6** wherein:
the upstream end of the combustion chamber includes a domed upstream closure member having a plurality of circumferentially spaced apart openings therein which alternately receive the fuel carbureting air swirlers and stabilizing air swirlers.

8. The combustion apparatus of claim **7** wherein:
the fuel carbureting air swirler means includes a swirl cup of the axial flow type, the fuel injector is housed within a centerbody centrally disposed within the swirl cup and the stabilizing air swirlers are of the radial flow type such that the core portions of the second vortical airflows are generally at a lower pressure than the core portions of the first vortical flows so as to provide improved flame holding stability within the combustion chamber.

* * * * *