United States Patent [19]

Hufnagel et al.

[11] **3,765,178**

[45] **Oct. 16, 1973**

[54] AFTERBURNER FLAMEHOLDER

[75] Inventors: **Robert Hughes Hufnagel**, Marblehead; **Lowell Jackson Pierce**, Melrose; **Edward Joseph Sabol**, Danvers, all of Mass.

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

[22] Filed: **Sept. 8, 1972**

[21] Appl. No.: **287,281**

[52] **U.S. Cl.** .... **60/261,** 60/39.32, 60/39.72 R, 69/39.74 R

[51] **Int. Cl.** **F02c 7/20,** F02c 7/22

[58] **Field of Search** .... 60/39.72 R, 39.74 R, 60/261, 39.32

[56] **References Cited**

UNITED STATES PATENTS

2,296,023	9/1942	Dallenbach et al.	60/39.72 R
2,679,137	5/1954	Probert	60/261 X
3,054,259	9/1962	Arthur	60/39.72 R
3,355,885	12/1967	Toone	60/39.72 R X
3,156,094	11/1964	Nash et al.	60/39.72 R X

Primary Examiner—Carlton R. Croyle
Assistant Examiner—Robert E. Garrett
Attorney—Edward S. Roman et al.

[57] **ABSTRACT**

An afterburner flameholder for an aircraft gas turbine engine is provided with a continuous annular inlet together with a closely adjacent inlet screen to meter gas flow from the turbine exhaust to a plurality of discrete pilot fuel jets within the flameholder. The wake behind the inlet screen is highly turbulent and operates to minimize temperature gradients existing in the inlet flow. The annular inlet communicates with smooth and uniformly flared flow passages through the flameholder thereby inhibiting local variations in flow velocity which heretofore were caused by sudden disruptions in the flowpath.

8 Claims, 4 Drawing Figures

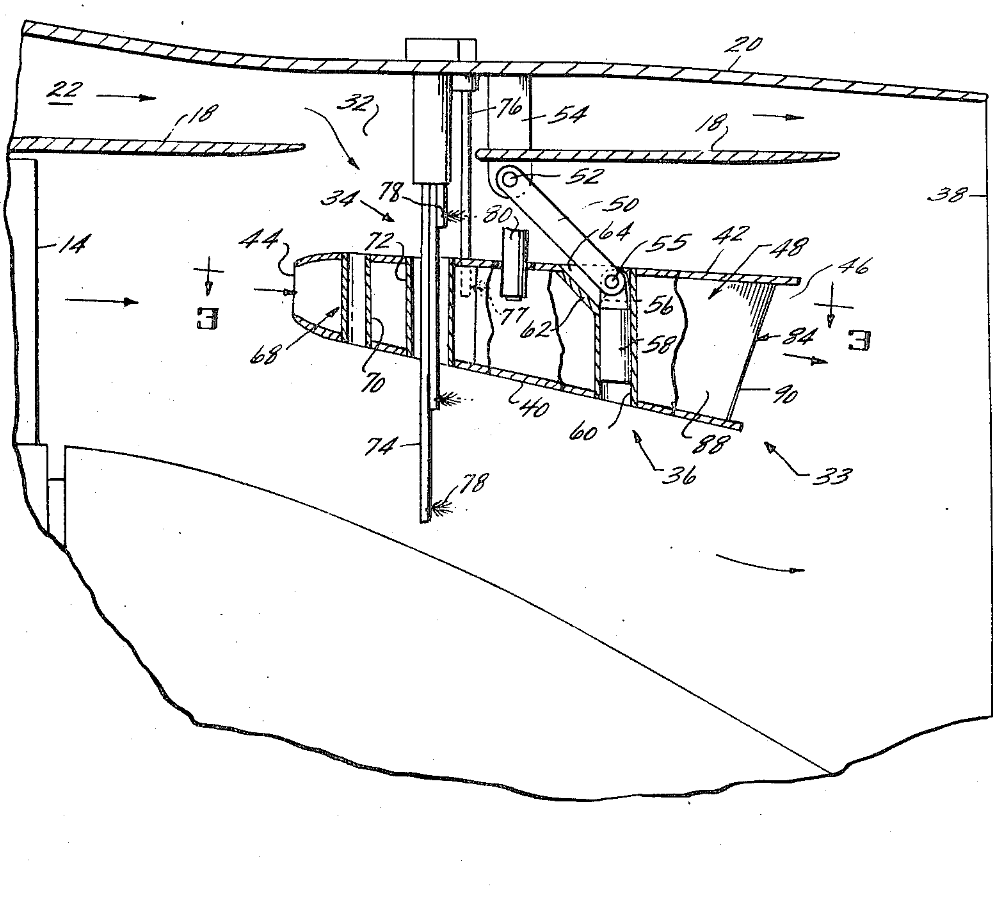


Fig 1

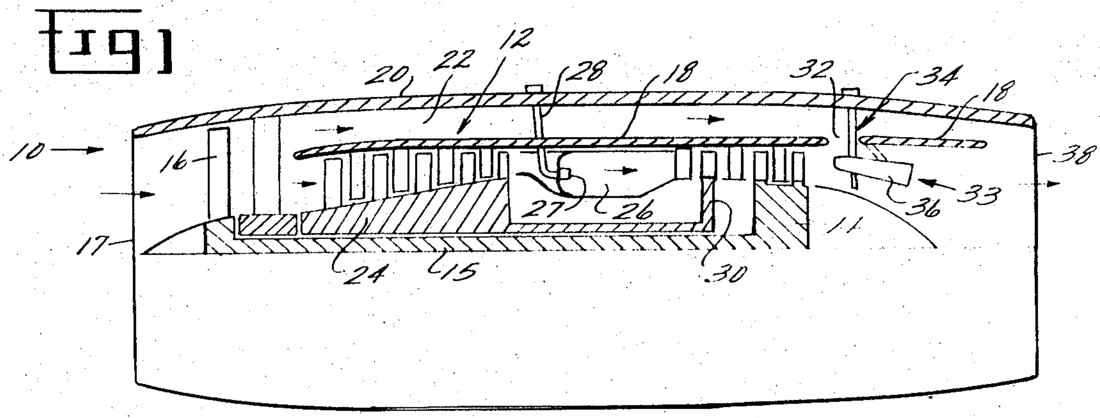

10
12
15
16
17
18
20
22
24
26
27
28
30
32
33
34
36
38
11

Fig 2

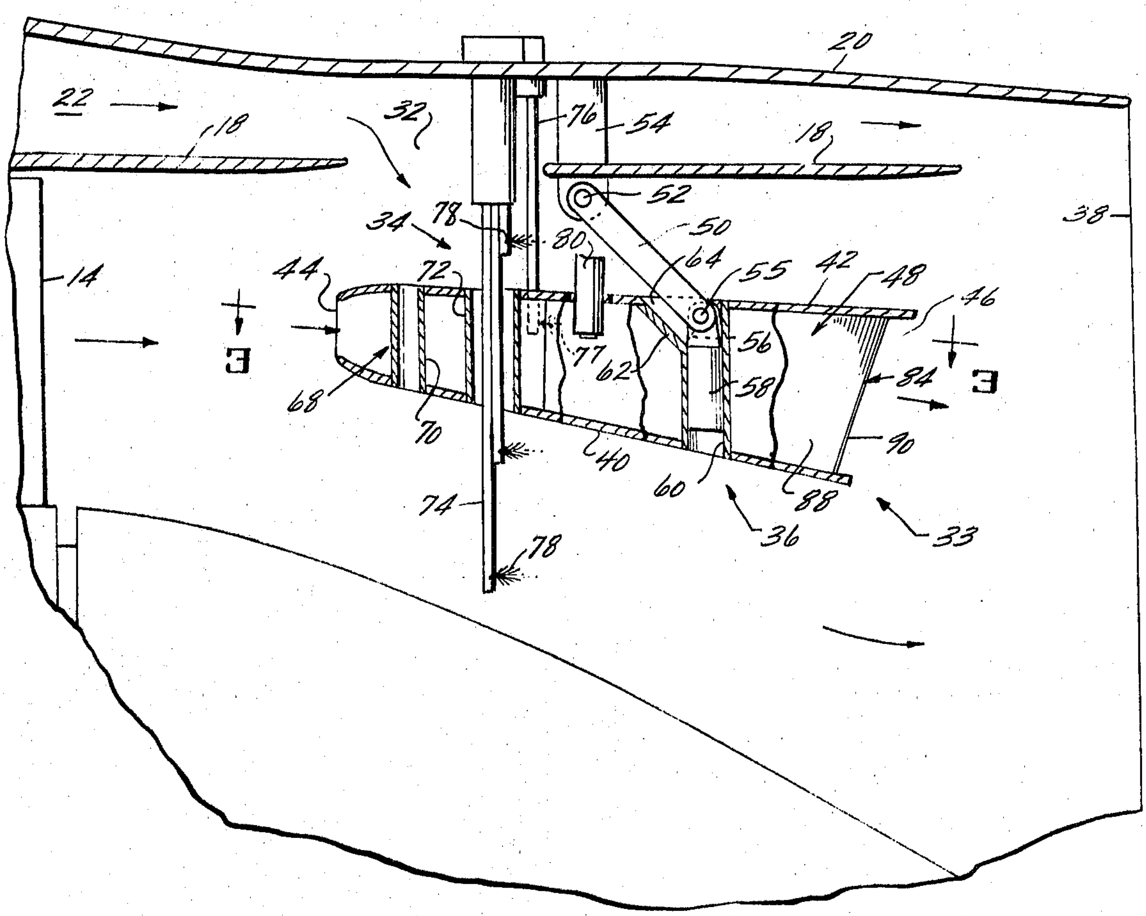

20
22
18
32
34
76
54
14
78
80
52
50
44
72
64
55
42
48
46
3
68
77
62
56
58
84
70
40
60
88
90
74
36
33

Fig 3

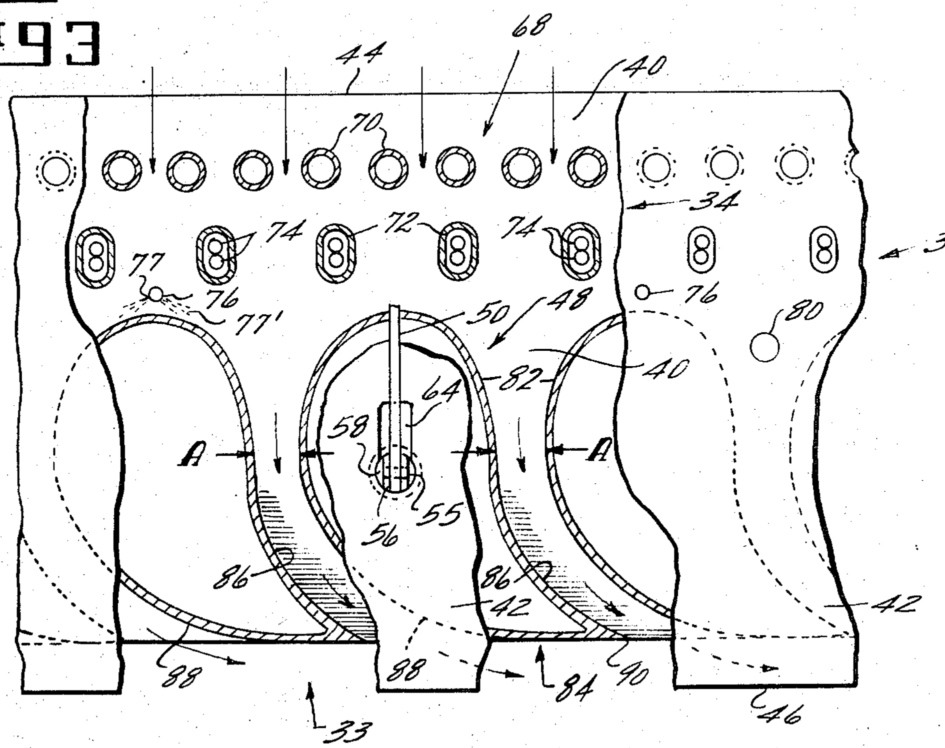
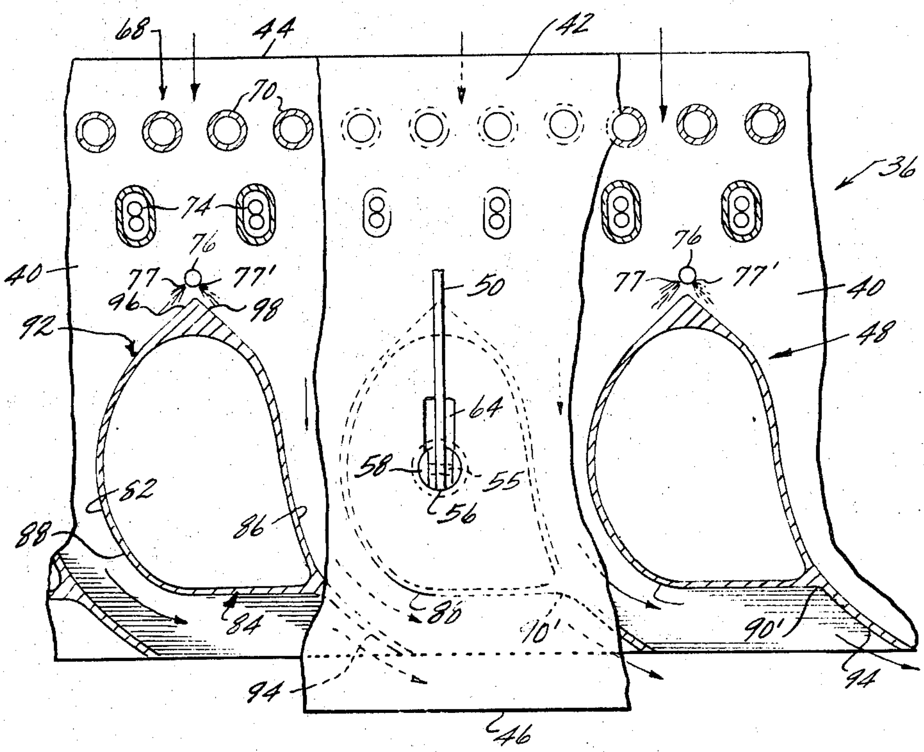

44
68
40
70
34
36
74
72
74
77
76
77'
76
80
50
48
40
82
64
58
A
A
55
56
86
86
42
42
88
88
84
90
33
46

Fig 4


68
44
42
70
36
74
76
77
77'
76
77
77'
40
40
50
96
98
92
48
64
58
55
56
82
88
86
86
10'
84
90'
94
94
46

AFTERBURNER FLAMEHOLDER

The invention herein described was made in the course of or under a contract or subcontract thereunder (or grant) with the Department of the Air Force.

BACKGROUND OF THE INVENTION

In general, this invention relates to an afterburner flameholder and, more particularly, to an afterburner flame-holder for inclusion within the gas stream of an aircraft gas turbine engine as part of an afterburning system to provide additional thrust augmentation.

It is well known in the aircraft gas turbine art to provide thrust augmentation by burning additional fuel in an afterburner located downstream of the engine turbine. The afterburner generally includes a means for dispersing a main flow of fuel together with a flameholder to which the flame may attach. The flameholder reduces locally the velocity of the gas stream in order to sustain the flame which would otherwise blow out. One well known type of flameholder comprises two concentric flame rings arranged to diverge from each other in a downstream direction. The main flow of fuel is dispersed in a manner that allows fuel droplets to impinge upon the outside diverging surfaces of the flameholder wherein the afterburning flame attaches to the trailing edges of the flame rings.

In order to provide for positive and uniform lightoff of the afterburner during all modes of flight operation, pilot fuel may be introduced and sparked to ignite by means of a point source igniter. The pilot flame in turn operates to ignite the main fuel droplets. It is well known to introduce the pilot fuel to the afterburner by means of discrete jets situated around the flameholder. The pilot fuel jets are generally located intermediate the flame rings such that each pilot jet receives gas flow from the turbine exhaust through an individual inlet opening in the leading edge of the flameholder.

The disadvantages to this arrangement are twofold. First, the temperature of the gas flow into the flameholder generally varies circumferentially around the flameholder. These circumferential temperature gradients are preserved by the conventional system of individual inlet openings for providing gas flow to the pilot fuel jets and can lead to localized overheating of the flameholder precipitating a condition commonly referred to as "hot streaking" wherein the flameholder rapidly deteriorates in the overheated areas.

The other disadvantage to conventional afterburner flame-holders relates to their susceptibility to phenomena commonly referred to as "flashback" and "preignition." Flashback can be generally described as an upstream propagation of the afterburner flamefront into the interior of the flameholder in the area between the flame rings, and may occur if the velocity of the flow through the flameholder falls off locally below the minimum velocity required to maintain flame attachment. Preignition is not as well understood as flashback, and relates to a sudden spontaneous ignition of the flow in the area between the flame rings of the flameholder. Preignition differs essentially from flashback in that the upstream preignition flame inside the flameholder exists independently of the downstream flame which remains attached to the flame ring trailing edges. Preignition may be a direct result of temperature gradients in the flow through the flameholder. The deleterious effects from flashback and preignition are essentially the same resulting in a premature localized burning of the flameholder components.

Flashback and preignition may also result from local velocity variations of the flow through the flameholder. Such non-uniform velocity profiles can result from abrupt area changes or discontinuities in the flowpath through the flameholder, and are common to conventional flameholders particularly those employing the system of individual inlet openings serving each pilot fuel jet.

Therefore it is an object of this invention to provide an afterburner flameholder, together with a system of pilot fuel jets wherein the gas flow inlet to the pilot fuel jets is designed to minimize temperature gradients in the gas flow through the flameholder.

It is also an object of this invention to provide a flameholder wherein the flowpath therethrough is smooth and uniformly flared without abrupt changes or discontinuities thereby reducing the risk of either flashback or preignition occurring.

SUMMARY OF THE INVENTION

A gas turbine engine of the type having a compressor, combustor, and turbine in serial flow relation is provided with thrust augmentation by an afterburner. The afterburner includes a flameholder having an inner flame ring, and an outer flame ring spaced radially outward and concentric to the inner flame ring. Means are further included for introducing a main flow of fuel outside the flame rings together with means for attaching the flame rings to the engine casing. According to the means of this invention, the outer ring in cooperation with the inner ring defines an annular inlet, for receipt of hot gas flow from the turbine, together with an annular outlet. An inlet screen is provided between the inner and outer flame rings closely adjacent the annular inlet for metering the flow between the flame rings and precipitating turbulence in the wake behind the screen. The high turbulence of the wake behind the screen operates to minimize any circumferential temperature gradients in the inflowing gas. Means are included for introducing pilot fuel in discrete jets downstream of the inlet screen. Circumferentially spaced apart airfoil type swirl vanes, radially extending between the inner and outer flame rings, are provided downstream of the pilot fuel injection means together with means for igniting the pilot fuel. The gas-fuel mixture is swirled in a circumferential direction by the swirl vanes in order to provide for a rapid propagation of flame around the entire flameholder.

DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims distinctly claiming and particularly pointing out the invention described herein, it is believed that the invention will be more readily understood by reference to the discussion below and the accompanying drawings in which:

FIG. 1 is a side elevational view partly in cross-section of a gas turbine engine of the turbofan type embodying the afterburner flameholder of this invention.

FIG. 2 is an enlarged cross-sectional view of the afterburner flameholder of FIG. 1.

FIG. 3 is a cross-sectional view taken along the line 3—3 of FIG. 2.

FIG. 4 is an alternate embodiment for the cross-sectional view taken along the line 3—3 of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, there is seen a turbofan engine **10** comprising a core engine **12** which generates a hot gas stream for driving a fan turbine **14.** The turbine **14** is connected to and drives the rotor **15** of a fan **16** disposed at the inlet end **17** of the engine. The core engine **12** qnd the fan turbine **14** are disposed within an inner casing **18.** An elongated cowl, or outer casing **20** defines the engine inlet indicated at **17** and, in combination with the casing **18,** defines a duct **22,** concentric of the core engine **12.**

In operation, the fan **16** pressurizes an air stream, the outer portion of which passes along the duct **22** and the inner portion of which enters the core engine **12.** In the core engine, the air stream is further compressed by a core engine compressor **24** to provide a highly pressurized air stream for supporting combustion of fuel in a combustor **26.** Fuel to the combustor **26** is provided by fuel injection means **27** which receives a flow of pressurized fuel through conduit **28** from a source of pressurized fuel (not shown). The hot gas stream thus generated drives a high pressure, core engine turbine **30** which is connected to the rotor of the compressor **24.** The hot gas stream passes through the fan turbine **14** and then it is intermixed with a portion of the bypass air from duct **22** entering through an annular passageway **32.**

Additional thrust augmentation may be provided by the afterburner shown generally at **33.** Additional fuel is introduced to the afterburner **33** through fuel inlet means **34** connecting to a source of pressurized fuel (not shown). Means for afterburner flame attachment are provided by flameholder **36,** the details of which will be made fully obvious from the discussion below.

The hot gas stream exiting from the afterburner **33** is discharged from a nozzle **38** to provide thrust for propulsion of an aircraft. Although the invention is described in relation to a turbofan engine, it could be applied with equal success to other types of gas turbine engines such as the straight turbojet engine.

Looking now to FIG. **2,** where like numerals refer to previously described elements, there is seen the flameholder **36** comprising an inner frusto conical flame ring **40** and an outer frusto conical flame ring **42.** The inner and outer flame rings **40, 42** are arranged in general concentric alignment so as to define an annular inlet **44** and an annular outlet **46** of greater cross-sectional area than the inlet. Radial separation between the flame rings is maintained by a plurality of circumferentially spaced apart and radially extending swirl vanes **48,** the profiles of which may be best seen in FIG. 3.

The flameholder ring **36** is attached to the inner casing **18** by means of a plurality of circumferentially spaced apart retaining links **50.** The outer radial ends of the retaining links **50** are rotatably pinned at pivot **52** to flange elements **54** which are in fixed connection between the inner casing **18** and the outer casing **20.** The inner radial end of each retaining link **50** is rotatably pinned at pivot **55** to clevis arrangement **56** extending radially outward of a piston **58.** Piston **58** is disposed within a sleeve **60** which extends through the inner and outer flame rings **40, 42** in generally central alignment with one of the swirl vanes **48.** In order to accommodate rotation of the retaining link **50** about the pivot **55,** a notch **62** must be provided through the outer flame ring **42,** and also the outer radial end **64** of sleeve **60** must be skewed relative to the longitudinal axis of the sleeve. The pivotal feature of the retaining links **50** is provided to accommodate thermal expansion of the flame rings **40, 42** which may result in a radially outward growth of the flameholder **36.** The number of retaining links **50** may be varied to suit particular hardware requirements with a minimial requirement of at least three retaining links spaced apart at equal intervals.

Adjacent the flameholder annular inlet **44,** there is provided an inlet screen **68** preferably comprising a plurality of circumferentially spaced apart and radially extending hollow cylinders **70.** The inlet screen **68** meters a pre-determined portion of the inlet gas flow through the confined passages of the flameholder **36.** Although other types of inlet screens would be well within the scope of the invention, spaced apart hollow cylinders **70** are preferred because the metered flow through the screen remains relatively insensitive to fluctuations in direction of the inlet gas flow. The hollow cylinders of the inlet screen **68** are also convenient to manufacture and easily accommodate to outward radial thermal growth.

The afterburner fuel inlet means **34** comprises a plurality of main fuel inlet conduits **74,** some of which extend radially through the flameholder **36.** Each main fuel inlet conduit **74** includes an aperture **78** closely adjacent the end thereof so as to discharge main jet streams of fuel about the outer surfaces of the flameholder **36.** The apertures **78** are spaced radially apart and oriented so as to discharge main jet streams of fuel in directions generally normal to the gas stream. A collar **72** is provided in spaced apart relation around the main fuel inlet conduits **74** to permit outward radial thermal expansion of the flameholder **36** without interference from the main fuel inlet conduits.

A pilot fuel conduit **76** terminates between the inner and outer flame rings **40, 42.** Each pilot fuel conduit **76** includes two circumferentially spaced apart apertures **77, 77′**, which may be best seen in FIGS. **3** and **4.** The apertures **77, 77′** are arranged to direct two divergent jet streams of pilot fuel, each stream of which flows through the nozzle defined by two adjacent swirl vanes **48.** The pilot fuel conduits **76** need only be located adjacent the leading edges of every other swirl vane **48** in order to provide a jet stream of pilot fuel to each nozzle. Igniter **80** provides a point source of spark to ignite the pilot fuel.

Referring now to FIG. **3,** there are shown the swirl vanes **48** which generally comprise a frusto conical main body portion **82.** An integral tail portion **84** extends rearwardly and circumferentially from the main body portion **82.** Side walls **86, 88** of the integral tail portion **84** converge rearwardly from tangential intersection with the frusto conical main body **82** and intersect at a swirl vane trailing edge **90.** The throat width A of each nozzle between adjacent swirl vanes **48** is selected to achieve the minimum gas flow velocity therethrough that will maintain flame attachment to the trailing edges **90.**

Describing now the operation of the foregoing structure for cases where additional thrust is required, the afterburner may be lit by first introducing pilot fuel through conduit **76,** whereupon the pilot fuel is sparked to ignite by igniter **80.** Inlet screen **68** meters a predetermined portion of the total gas flow through the annular inlet **44** so as to achieve the desired stoichiometric ratio of fuel to air. The hollow cylinders or rods **70** provide for a highly predictable and uniform metered flow through the flameholder.

As previously discussed, the temperature of the gas flow into the flameholder **36** may vary circumferentially around the flameholder. Such circumferential temperature gradients can precipitate hot streaks within the flameholder leading to rapid localized deterioration of the flameholder. The wake behind the inlet screen **68,** however, provides a high level of turbulence so as to thoroughly mix the incoming gas flow, thereby minimizing the circumferential temperature gradients which can lead to the premature deterioration of the flameholder. Therefore, the continuous annular inlet feature of the flameholder of this invention coupled with the inlet screen provides a marked advantage over conventional flameholders having individual discrete inlet openings servicing each pilot fuel jet.

The turbulent wake behind the inlet screen **68** also provides for a high degree of mixing and dispersing of pilot fuel within the hot incoming gas. This highly uniform gas-fuel mixture flows downstream between the swirl vanes **48** to the flame zone which is desirably maintained behind the swirl vane trailing edges **90.** The gas-fuel mixture is swirled in a circumferential direction in order to provide for a rapid propagation of flame around the entire flameholder from the initial point of spark at igniter **80.** Main fuel is ignited by the annular pilot flame in a conventional manner.

One problem previously encountered with afterburner flameholders relates to the previously discussed phenomenon called flashback, which is an upstream propagation of the afterburner flame front into the interior passages of the flameholder. Flashback may occur if the velocity of the fuel-gas mixture between the swirl vanes **48** falls off below the minimum speed required to maintain flame attachment at the swirl vane trailing edges **90.** Another phenomenon previously discussed is preignition which is not as well understood as flashback and relates to a sudden spontaneous ignition of the fuel-gas mixture in an area upstream of the swirl vane trailing edges **90.** Preignition differs essentially from flashback in that the upstream preignition flame inside the flameholder is separate and distinct, existing independently of the downstream flame attached to the swirl vane trailing edges **90.** However, the deleterious effects from flashback and preignition are essentially the same resulting in a premature localized burning of the flameholder components. Preignition may be a direct result of the circumferential temperature gradients previously discussed. Therefore, the probability of preignition occurring in the flameholder of this invention is believed to be minimized by the thorough mixing effect of the highly turbulent wake behind the inlet screen **68.**

Local variations in velocity and flow direction may also contribute to preignition and flashback. Therefore, it is desirable that the velocity profile be kept uniform and predictable over all cross-sections taken between the plane of pilot fuel injection at inlet conduit **76** and the plane defined by the swirl vane trailing edges **90.** However, if the flow paths through the afterburner are designed with abrupt area changes or discontinuities as has been the case for conventional afterburner flameholders, then local perturbations and eddies will develop and disrupt the uniform nature of the velocity profiles. These preturbations and eddies will cause the velocity of the gas-fuel mixture approaching the swirl vane trailing edges **90** to fall off locally below the minimum velocity required to maintain flame attachment at the trailing edges. In such cases the afterburner flamefront will propagate upstream into the interior passages of the flameholder at those areas of flow velocity disruption causing localized overheating and burning of the flameholder components.

The flow passages of the flameholder of this invention, however, have been specifically designed to be smooth and uniformly flared with no sudden area changes or discontinuities in the passageways between the plane of pilot fuel injection at inlet conduit **76** and the plane defined by the swirl vane trailing edges **90.** The high turbulence of the wake behind the inlet screen **68** becomes substantially exhausted before reaching the swirl vane trailing edges **90** so as to provide a substantially uniform velocity profile at the trailing edges **90.** Swirl vanes **48** are essentially airfoil shaped with gradually contoured sides presenting no sharp discontinuities to the fuel-gas flow therethrough which could precipitate localized flashback or preignition. As is readily obvious, the geometric configuration is simple and provides for a readily predictable flow between the swirl vanes. The configuration also lends itself for economical low cost tooling and manufacture.

Referring now to FIG. **4,** there is shown a slight modification of the swirl vanes **48.** A sharp integral leading edge portion **92** has been included forward of the main body portion **82** and includes sidewalls **96, 98** converging forward from tangential intersection with the main body **82,** thereby streamlining the aerodynamic profile of each swirl vane **48.** Also sidewall **86** of the integral tail portion has been extended rearwardly and circumferentially at **94** beyond the line of intersection **90'** of the converging sidewalls **86, 88.** The angle of discharge of the gas-fuel mixture from swirl vanes **48** may therefore be made to more nearly approximate the circumferential direction, thereby reducing the overall time required for flame propagation around the annular flameholder. Also, convective cooling of the vane trailing edges is further facilitated by this arrangement.

Various changes could be made in the structures shown in FIGS. **1** through **4** without departing from the scope of the invention. The swirl vanes **48** may be of any suitable airfoil cross-section so long as a prescribed and predictable flow can be achieved between the vanes. The inlet screen **68** could alternatively be a reticulate configuration. Therefore, having described preferred embodiments of the invention, though not exhaustive of all possible equivalents, what is desired to be secured by letters patent is claimed below.

What is claimed is:

1. In a gas turbine engine of the type having a casing enveloping a compressor, combustor, and turbine in serial flow relation, augmentation is provided by an afterburner comprising:

an inner flame ring;

an outer flame ring, spaced radially outward and concentric to the inner flame ring, which in cooperation with the inner flame ring defines an annular inlet for receipt of hot gas flow from the turbine, together with an annular outlet;

an inlet screen between the inner and outer flame rings closely adjacent the annular inlet for metering the flow between the flame rings wherein the turbulence of the wake behind the screen minimizes circumferential temperature gradients of the gas inflow;

means for introducing pilot fuel in discrete jets downstream of the inlet screen;

circumferentially spaced apart airfoil type swirl vanes radially extending between the inner and outer flame rings downstream of the pilot fuel means;

means for igniting the pilot fuel;

means for introducing a main flow of fuel outside the flame rings, and

means for maintaining the flame rings in fixed relation relative to the engine casing.

2. The afterburner of claim **1** wherein the attaching means comprise a plurality of retaining links pivotally connected at one end to the engine casing; and

a plurality of pistons radially disposed in connection to the flame rings and pivotally connected to the other ends of the retaining links, thereby accommodating thermal expansion of the flame rings.

3. The afterburner of claim **1** wherein:

the inner and outer flame rings are conical frustums cooperatively arranged to define an annular rearwardly diverging passageway.

4. The afterburner of claim **1** wherein:

the inlet screen comprises a plurality of circumferentially spaced cylinders extending radially between the inner and outer flame rings.

5. The afterburner of claim **1** wherein each swirl vane comprises a generally frusto conical main body portion with an integral tail portion extending rearwardly and circumferentially from the main body portion with the sidewalls of the integral tail portion converging rearwardly from tangential intersection with the frusto conical main body into intersection at the swirl vane trailing edge.

6. The afterburner of claim **5** wherein each swirl vane includes a sharp integral leading edge portion extending forward of the main body portion with the sidewalls of the integral leading edge portion converging forwardly from tangential intersection with the frusto conical main body into intersection at the swirl vane leading edge and wherein:

a sidewall of the integral tail portion extends rearwardly and circumferentially beyond the line of intersection of the converging tail portion sidewalls.

7. The afterburner of claim **1** wherein:

the pilot fuel means includes an inlet conduit terminating between the flame rings at a point closely adjacent the leading edge of a swirl vane and having two spaced apart apertures for directing individual jets of pilot fuel on each side of the adjacent swirl vane, and wherein:

the main fuel means includes a plurality of inlet conduits terminating radially outward and inward of both flame rings, each conduit of which includes an aperture for directing a jet of main fuel outside the flame rings.

8. A flameholder comprising:

an inner flame ring;

an outer flame ring spaced radially outward and concentric to the inner flame ring which in cooperation with the inner flame ring defines an annular inlet and outlet;

an inlet screen between the inner and outer flame rings closely adjacent the annular inlet for metering the flow between the flame rings wherein the turbulence of the wake behind the screen minimizes circumferential temperature gradients of the inflow;

means for introducing pilot fuel in discrete jets downstream of the inlet screen;

circumferentially spaced apart airfoil swirl vanes radially extending between the inner and outer flame rings downstream of the pilot fuel means; and

means for igniting the pilot fuel.

* * * * *