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Howald

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[54] **ANNULAR COMBUSTOR SYSTEMS**

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[52] **U.S. Cl.** ..... **60/39.74 R**

[51] **Int. Cl.** **F02g 1/00**

[58] **Field of Search** 60/39.74, 39.65

[56] **References Cited**

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[57] **ABSTRACT**

An annular combustor system is illustrated in a gas turbine engine environment. Compressor discharge air is diffused in a short length diffuser into a closely spaced plenum formed by a bluff bodied, annular array of fuel injectors and the upstream ends of liners which define, in part, an annular combustion zone. The compressor discharge air is evenly distributed in the plenum and then passes through and around the fuel injectors to break up the fuel and support its combustion in a short flame front having a uniform temperature distribution. Plenums surround the liners. Air from the diffuser pressurizes these plenums and is then metered by holes in the liners to provide cooling films on the inner surfaces thereof.

6 Claims, 4 Drawing Figures

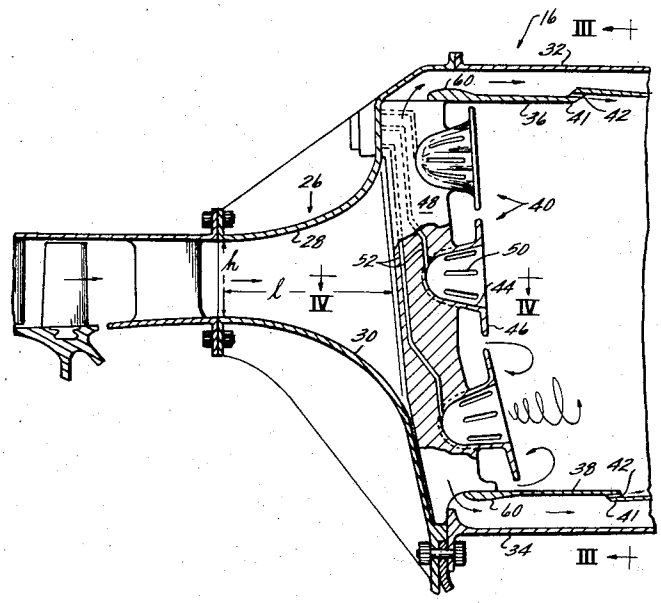


Fig 1

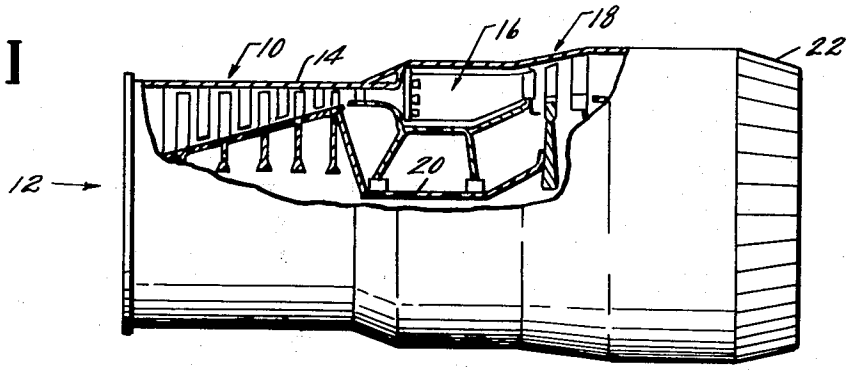
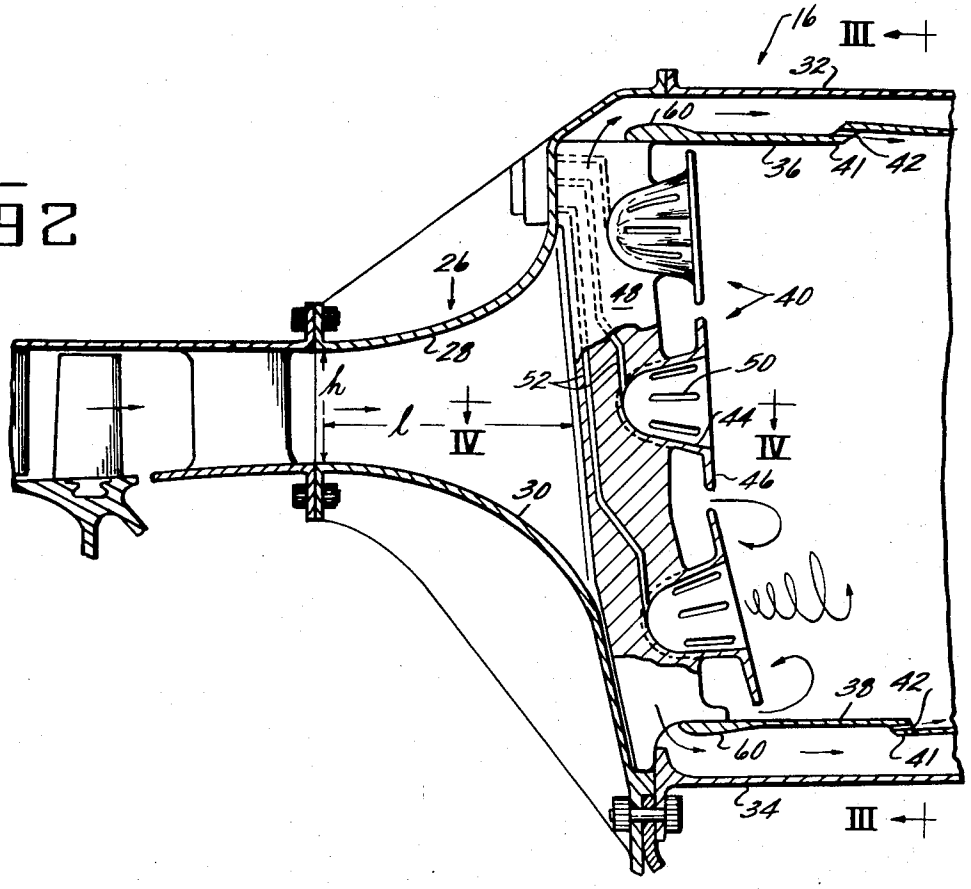


Fig 2



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Fig 3

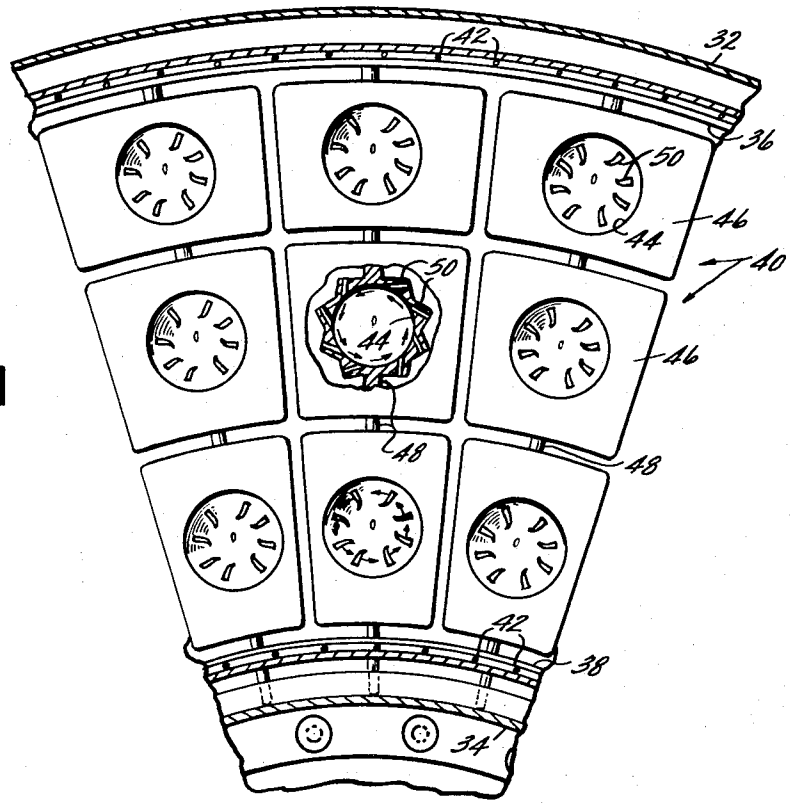
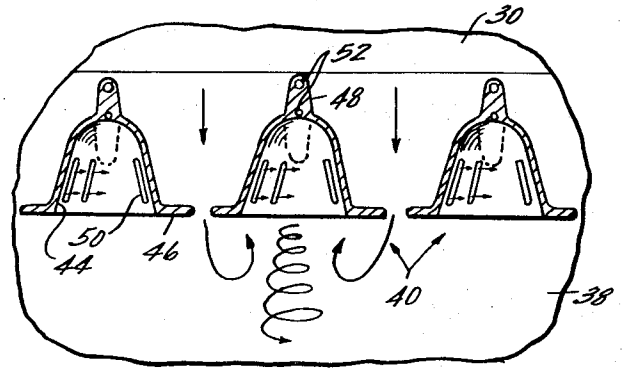


Fig 4



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ANNULAR COMBUSTOR SYSTEMS

The present invention relates to improvements in combustor systems, particularly of the type incorporated in gas turbine engines.

Gas turbine engines comprise a compressor for pressurizing an annular air stream. This pressurized air stream then supports combustion of fuel in a combustion zone to generate a high energy hot gas stream. The hot gas stream drives a turbine to power the compressor rotor and is then converted to a useful output, as by being discharged from a propulsion nozzle.

Combustion systems as herein contemplated include liners for defining the axial extent of the combustion zone, the means for injecting fuel into the combustion zone and the means for distributing pressurized air from the compressor and introducing it into the combustion zone.

A common problem associated with such systems is that hot spots and/or hot streaks are created in the combustion zone which result in thermal gradients in the hot gas stream discharged from the combustor system as well as thermal gradients in the liners. The thermal gradients in the hot gas stream cause local hot spots in the turbine components to which it is discharged.

The thermal gradients in the metal parts, i.e., liners and turbine components, limit the energy level of the hot gas stream since temperature limitations are imposed by the hottest metal temperatures and not average metal temperatures. Also, sharp temperature gradients can induce thermal stresses which further reduce the average, safe operating temperature and the available energy level of the hot gas stream.

Accordingly, one object of the invention is to minimize thermal gradients in an annular combustion system.

Another factor influencing the design of combustor systems, particularly those for gas turbine engines employed in the propulsion of aircraft, is the desire for reduced weight. One obvious way to reduce weight is to shorten the length of the combustor system. However, to do so has generally, in the past, increased the problems of thermal gradients.

Copending Application Ser. No. 352, filed on even date with the present application in the names of Eric S. Collinson and the present Applicant and of common assignment, discloses an effective approach to shortening a portion of the combustor system. More specifically, that application teaches a combination of fuel injectors which reduce the length of the combustion zone and thus reduce the length and weight of the liners which define this zone.

Another object of the invention is to reduce the length and weight of combustor systems and particularly to provide, in combination with the concepts of the above-referenced application, a combustion system of minimum length and weight wherein thermal gradients are minimized, all toward the end of enabling increases in the average temperature and energy level of the hot gas stream generated by the combustor system.

In its primary aspects the present invention relates to delivery of pressurized air to an annular combustion zone. Pressurized air discharged from the compressor of an engine is diffused by a unique, short length diffuser. Separation and other losses in this diffuser are minimized by a bluff body closely spaced therefrom and defining the upstream end of the combustion zone. The liners for the combustion zone extend upstream of the bluff body to form an annular plenum opening toward the diffuser discharge.

The bluff body preferably takes the form of an array of fuel injectors, each comprising a divergent cup opening into the combustion zone and a baffle plate projecting therefrom. The diffused air is evenly distributed over the upstream side of this array and flows through and around the fuel injectors to maintain a uniform, short length flame front in the combustion zone.

Plenums also surround the liners. These plenums are pressurized by the combustor discharge and air is metered by holes in the liners to maintain a film of cooling air along the inner surfaces of the liners.

The above and other related objects and features of the invention will be apparent from a reading of the following description of the disclosure found in the accompanying drawings and the novelty thereof pointed out in the appended claims.

IN THE DRAWINGS:

FIG. 1 is a schematic illustration, partly in section, of a gas turbine engine embodying the present invention;

FIG. 2 is an enlarged, longitudinal section, through the combustion system, of this engine;

FIG. 3 is a section taken on line III—III in FIG. 2; and

FIG. 4 is a section, taken on line IV—IV, in FIG. 2.

The engine seen in FIG. 1 comprises a multistage, axial flow compressor **10** which pressurizes air entering an inlet **12** at one end of a casing **14**. The pressurized air is discharged from the compressor into a combustor system **16** where it supports combustion of fuel to generate a hot gas stream. Part of the energy of the hot gas stream is used to drive a turbine **18**. The rotors of the turbine **18** and compressor **10** are joined by a shaft **20** to power the compressor. The remainder of the recoverable energy of the hot gas stream may be converted to a propulsive force by discharging it from a nozzle **22**. Gas turbine engines take many forms and the above is intended as illustrative.

Pressurized air is discharged from the compressor **10** to an annular diffuser **26** having divergently curved, annular walls **28, 30** which are joined at their outer ends to outer and inner casings **32** and **34**, respectively. The combustion zone is defined by liners **36, 38** and fuel injectors **40** at their upstream ends.

The liners **36, 38** are preferably formed in accordance with U.S. Pat. No. 3,420,058, with circumferential steps **41**, through which angularly spaced holes **42** are formed generally parallel to or at an angle toward the inner surface of the liner portion downstream thereof. The holes **42** are closely spaced so that cooling air introduced therethrough forms an essentially uniform cooling film on the inner surfaces of the liners.

The fuel injectors **40**, as taught in the referenced, copending application, comprise divergent, hemispherical cups **44** opening generally centrally of baffle plates **46**. The fuel injectors **40** are radially aligned in three circumferential rows with the baffle plates **44**, in the form of segments, evenly spaced from each other and from the adjacent liners **36, 38** to provide a uniform

mass flow of air therearound. The fuel injectors of each aligned row are formed integrally with airfoil struts **48**. Fuel passageways **52** extend through the struts **48** and discharge fuel tangentially into the rear of each cup **44**. The fuel is broken up by a vortical flow of air through the tangential slots **50** formed in each cup **44** and then further broken up by the vortical flow of air around the peripheries of the baffle plates **46**. The air vortices and the multiple injector form a very short and stable flame front in the combustion zone, as is more fully described in the referenced, copending application.

Reverting to the diffuser **26**, it will be noted that its divergently curved walls **30, 28** have an extreme curvature and that, for its axial length, the diffuser has an area ratio (area out/area in) much greater than conventional diffusers of the wall-attachment type. The diffuser is more particularly characterized as having an inlet height, *h*, to axial length, *l*, ratio (*h*/*l*) of 4/1 or less and an area ratio of 2.5/1 or greater. The described diffuser provides recovered pressures (equated with high efficiency) comparable to diffusers of conventional divergence having a much greater axial length.

This feature is attributable to the bluff bodied nature of the array of fuel injectors **40** and the close proximity of this array to the diffuser outlet. "Bluff body" as herein used means an annular structure of substantially the discharge height of the diffuser and lying in a plane generally normal to the direction of air flow from the diffuser. Further, the liners **36, 38** project upstream of the bluff body formed by the baffle plates **46** providing an annular plenum having its center of area aligned with the center of area of the annular diffuser **26**. This arrangement most efficiently turns the compressor discharge air around the curved diffuser walls **30, 28** with little or no separation.

As the compressor discharge air is thus diffused, its velocity is proportionately reduced and then further reduced as it flows into the annular plenum. Such a significant reduction in air velocity provides an equal pressure distribution over the upstream sides of the fuel injectors with a minimum of losses.

The equal pressure distribution within the annular plenum enables the fuel injectors **40** of each circumferential row to be manufactured with identical configurations providing equal mass flow rates of air to each injector. With equal fuel flow rates to the injectors, the rate of combustion at each injector is accurately and evenly controlled within a localized area of the relatively short flame front immediately downstream of the fuel injector array.

In this latter connection, it will be noted that essentially all of the air for the combustion process to be carried out, in the combustion zone of the combustor, is introduced through and around the fuel injectors **40**. With the described equalized distribution of air flow the combustion process is highly uniform in a circumferential sense to minimize thermal gradients. The minimal thermal gradients further minimize the axial length of the liners which might otherwise be required to dissipate such gradients by mixing, as by the addition of dilution air through holes in the liner.

The air introduced through the holes **42** is for the purpose of cooling the liners **36, 38** and is not for the purpose of diluting any hot streaks in the combustion stream as is common in conventional combustors. The cooling air is metered by the holes **42** to provide an essentially uniform insulating film on the inner surfaces of the liners which is replenished by each succeeding, circumferential row of closely spaced holes.

In this connection it will be noted that the annular spaces between the liner **36** and outer casing **32** and between the liner **38** and the inner casing **34**, respectively form plenums having essentially uniform pressure and flow velocity therein. Compressor discharge air flows freely from the diffuser **26** through annular openings, defined by the upstream edges of the liners **36, 38**, into these plenums. The upstream edges of the liners **36, 38** are in the form of thickened lips **60** to accelerate the air and minimize turning losses as it enters the cooling air plenums. While there may be other components supplied with cooling air (or compressor discharge air) from these plenums, the entrances thereto are sufficient to maintain the aforereferenced equal, or controlled, pressure distributions. This relationship is significant in maintaining a predetermined, uniform distribution of cooling air along the inner surfaces of the liners **36, 38**.

Variations in the preferred embodiment, disclosed herein, will occur to those skilled in the art within the spirit and scope of the present inventive concepts as defined by the following claims.

Having thus described the invention, what is claimed as novel and desired to be secured by Letters Patent of the United States is:

1. A combustor system for generating a hot gas stream by the combustion of fuel in a pressurized air stream discharged from a compressor, said system comprising,

a pair of liners respectively defining the inner and outer bounds of an annular combustion zone,

an annular bluff body at the upstream ends of said liners,

means for injecting fuel into said combustion zone adjacent said bluff body, said bluff body having a plurality of evenly distributed openings thereto for the introduction of pressurized air into said combustion zone,

an annular diffuser connected at its upstream end to the compressor discharge and divergently curved to provide high pressure, low velocity air evenly distributed over the upstream side of said bluff body for introduction into said combustion zone, wherein

an annular plenum is formed upstream of said bluff body and opening toward said diffuser discharge, and wherein

the annular diffuser has a ratio of its inlet height to its axial length of no greater than approximately 4:1 or less and an area ratio of at least approximately 2.5:1.

2. A combustor system for generating a hot gas stream by the combustion of fuel in a pressurized air stream discharged from a compressor, said system comprising,

a pair of liners respectively defining the inner and outer bounds of an annular combustion zone,

an annular bluff body at the upstream end of said liners,

means for injecting fuel into said combustion zone adjacent said bluff body, said bluff body having a

plurality of evenly distributed openings therethrough for the introduction of pressurized air into said combustion zone,

an annular diffuser connected at its upstream end to the compressor discharge and divergently curved to provide high pressure, low velocity air equally distributed over the upstream side of said bluff body for introduction into said combustion zone, wherein

an annular plenum is formed upstream of said bluff body and opening toward said diffuser discharge, and wherein

the bluff body is in the form of a plurality of angularly and radially spaced fuel injectors, each fuel injector comprising a cup opening toward said combustion zone and having a plate projecting outwardly from said cup, the plates of said fuel injectors being spaced apart from each other and spaced from adjacent liners to provide openings for the introduction of pressurized air into said combustion zone, each fuel injector further comprising a passageway for the introduction of fuel into said cup and tangential slots in said cup for introduction of further pressurized air into said combustion zone.

3. A combustion system as in claim **2** wherein, the diffuser has a ratio of its inlet height to its axial length of no greater than approximately 4/1 and an area ratio of at least approximately 2.5/1.

4. A combustion system as in claim **3** wherein,

casings are respectively spaced from the outer surfaces of said liners to form liner plenums,

said liners extend upstream of the plates of said fuel injectors to form the annular plenum opening towards said diffuser discharge, the upstream edges of said liners being spaced from said diffuser to define entrances to the liner plenums and

the liners have openings therethrough for the introduction of cooling air along their inner surfaces.

5. A combustion system as in claim **4** wherein, the entrances to said liner plenums are in the form of nozzles to accelerate the air entering the plenum and thus minimize entrance losses.

6. A combustion system as in claim **5** wherein, the liners have circumferential steps along their lengths and the openings in the liners are in the form of holes through said steps, directing cooling air along the interior surfaces of the liner immediately downstream of the respective steps.

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