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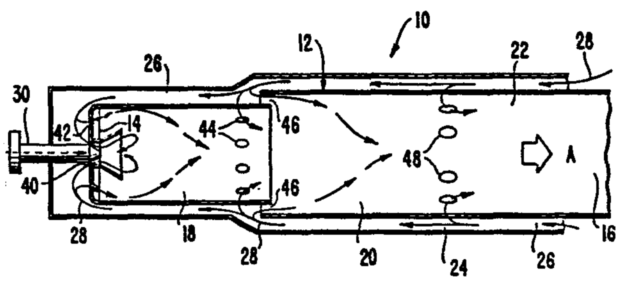
(71) Applicant: A/S Kongsberg Väpenfabrikk,
Kirkegardsveien, N-3600 Kongsberg (NO)

(72) Inventor: Strom, Sigmunn, Mosekollen 6,
N-3600 Kongsberg (NO)

(74) Representative: Jackson, David Spence et al, REDDIE & GROSE 16, Theobalds Road, London, WC1X 8PL (GB)

(54) **Gas turbine engine combustor.**

(57) A gas turbine engine combustor (10) has a two-stage burner (12) having first and second combustion sections (18, 20) and an exhaust section (22) and a burner casing (24) coaxially surrounding these sections (18, 20, 22) to define an annular conduit (26) for reverse flow (28) of inlet air. A fuel injector (30) is situated at the upstream end. Primary inlet ports (40) introduce 18% of inlet air into the first combustion section (18), and first cooling ports (42) introduces 12% of inlet air into the first combustion section (18) for generating a swirling cooling flow which mixes with primary air after cooling the upstream end of the first combustion section (18). Secondary inlet ports (44) introduces 18% of inlet air into second stage combustion section (20), and second cooling ports (46) introduces 8% of inlet air into the second combustion section to generate a swirling flow which mixes with primary air after cooling the upstream end of the second combustion section (20). Dilution ports (48) introduces 44% of inlet air into the exhaust section (22) to cool the exhaust gas.



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GAS TURBINE ENGINE COMBUSTOR

The present invention relates to combustors for gas turbine engines and, in particular, to a convectionally-cooled 2-stage combustor with low pressure loss and uniform exhaust temperature.

Various types of known combustors or combustion chambers for gas turbine engines are described and discussed in Boyce, Gas Turbine Engineering Handbook, Chapter 10, pp.281-301 (1982). As noted in this reference, combustor performance is measured by efficiency, pressure loss, and temperature profile or distribution.

The present invention is directed to a combustor for a gas turbine engine having low air velocity and two stage burning which provides an overall temperature distribution factor in the range of 0.07 to 0.12. This is achieved by use of convection cooling and avoidance of conventional film cooling of the combustor walls and a specific distribution of inlet air entering into the combustor.

The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

In accordance with the invention, as embodied and broadly described herein, the combustor for a gas turbine engine comprises a burner defining an axial fluid-flow path between upstream and downstream ends thereof, the burner including a first combustion section proximate the upstream end, a second combustion section axially downstream of the first combustion section, and an exhaust section proximate the downstream end; a burner casing coaxially surrounding the burner and defining an annular conduit for flow of inlet air from downstream to upstream ends of the burner, the inlet air flow convectionally cooling the burner; means at the upstream end of the burner for introducing fuel into the first combustion section; first primary means for introducing a first primary portion of the inlet air into the first combustion section to generate a combustible fuel-air mixture therein; first cooling means for introducing a first cooling portion of the inlet air into the first combustion section to generate a swirling flow of first cooling air therein, the swirling flow of first cooling air creating an annular cooling layer proximate the upstream end of the first combustion section which substantially mixes with the first primary portion downstream in the first combustion section; second primary means for introducing a second primary portion of the inlet air into the second combustion section to generate a combustible fuel-air mixture therein; second cooling means for introducing a second cooling portion of the inlet air into the second combustion section to generate a swirling flow of second cooling air therein, the swirling flow of second cooling air creating an annular cooling layer proximate the upstream end of the second combustion section which substantially mixes with the second primary portion downstream in the second combustion section; and dilution means for introducing a dilution portion of the inlet air into the exhaust section to cool the exhaust gas of the burner.

Preferably, the first primary means comprises a plurality of first primary openings at the upstream end of the burner disposed around the fuel introducing means, the first cooling means comprises a plurality of first cooling openings at the upstream end of the burner disposed in an annular array radially outward of the first primary openings, the second primary means comprises a plurality of radially oriented second primary openings circumferentially spaced about the burner proximate the downstream end of the first combustion section, the second cooling means comprises a plurality of axially oriented second cooling openings circumferentially spaced about the burner proximate the downstream end of the first combustion section, and the dilution means comprises a plurality of radially oriented dilution openings circumferentially spaced about the burner proximate the downstream end of the second combustion section.

In a preferred embodiment, the first primary portion is approximately 18% of inlet air, the first cooling portion is approximately 12% of inlet air, the second primary portion is approximately 18% of inlet air, the second cooling portion is approximately 8% of inlet air, and the dilution portion is approximately 44% of inlet air.

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate one embodiment of the invention, and together with the description, serve to explain the principles of the invention.

FIGURE 1 is a longitudinal cross-sectional view of an embodiment of the invention.

FIGURE 2 is an enlarged, partial cross-sectional view of part of the combustor depicted in FIGURE 1.

Reference will now be made in detail to the present preferred embodiment of the invention, an example of which is illustrated in the accompanying drawings.

The combustor of the invention comprises a burner defining an axial fluid-flow path for gases between upstream and downstream ends thereof and including a first combustion section proximate the upstream end, a second combustion section axially downstream of the first combustion section and an exhaust section proximate the downstream end.

As depicted in Figure 1, the combustor 10 includes a burner 12 defining an axial fluid-flow path A between an upstream end 14 and a downstream end 16. The burner includes a first combustion section 18 proximate upstream end 14, a second combustion section 20 axially downstream of first combustion section 18 and an exhaust section 22 proximate downstream end 16.

In accordance with the invention, the combustor includes a burner casing coaxially surrounding the burner and defining an annular conduit for flow of inlet air from downstream to upstream ends of the burner, the inlet air flow convectionally cooling the burner. In the embodiment of Figure 1, burner casing 24 coaxially surrounds burner 12 and defines an annular conduit 26 for flow of inlet air depicted by arrows 28 from downstream end 16 to upstream end 14. Inlet air flow 28 convectionally cools burner 12 by flowing along the outside surface of the burner. Inlet air 28 is generated by the compressor (not shown) of the gas turbine engine and conveyed to annular conduit 26 by conduit means (not shown).

Also in accordance with the invention, the combustor includes means for introducing fuel into the burner proximate the upstream end thereof. Fuel nozzle 30, as seen in Figures 1 and 2, projects through upstream end 14 of burner 12 to inject fuel into first combustion section 18.

In accordance with the invention, the combustor includes a first primary means for introducing a first primary part of the inlet air into the first combustion section to generate a combustible fuel-air mixture therein.

Preferably, as seen in Figures 1 and 2, the first primary means comprises a plurality of first primary openings 40 in upstream end 14 of burner 12 disposed around fuel nozzle 30. About 18% of the inlet air 28 flowing through annular conduit 26 enters first combustion section 18 through first primary openings 40 and mixes with fuel injected into first combustion section 18 by fuel nozzle 30. Various structural features may be incorporated within first combustion section 18 proximate fuel nozzle 30 to generate swirling and mixing action between inlet air and fuel.

In accordance with the invention, the combustor includes a first cooling means for introducing a first cooling portion of the inlet air into the first combustion section to generate a swirling flow of first cooling air therein. The swirling flow of first cooling air creates an annular cooling layer proximate the upstream end of the first combustion section which substantially mixes with the first primary portion downstream in the first combustion section.

Preferably, first cooling means comprises a plurality of first cooling openings 42 in the upstream end 14 of the burner 12. First cooling openings 42 are disposed in an annular array radially outward of first primary openings 40. Approximately 12% of inlet air 28 flowing through annular conduit 26 enters first combustion section 18 through first cooling openings 42. First cooling openings 42 are so arranged as to generate a swirling action of cooling air in the upstream end of first combustion section 18. The swirling action of the cooling air generates an annular layer of cooling air at the upstream end of section 18 which is then mixed with the primary air downstream in section 18. The annular layer of cooling air, known as film cooling, does not extend to the downstream end of the first combustion section 18.

In accordance with the invention, the combustor includes a second primary means for introducing a second primary part of inlet air into the second combustion section to generate a combustible fuel-air mixture therein. Preferably, second primary means comprises a plurality of radially-oriented second primary openings 44 circumferentially spaced about burner 12 proximate the downstream end of first combustion section 18. Approximately 18% of inlet air 28 enters first combustion section 18 at the downstream end thereof through openings 44 and mixes with combustion gases exiting from first combustion section 18 to generate a second stage of burning in second combustion section 20.

The combustor of the invention also includes second cooling means for introducing a second cooling portion of inlet air into the second combustion section to generate a swirling flow of second cooling air. The swirling flow of second cooling air creates an annular cooling layer proximate the upstream end of the second combustion section which substantially mixes with the second primary portion downstream in the second combustion section.

Preferably, second cooling means comprises a plurality of axially-oriented second cooling openings circumferentially spaced about the burner proximate the downstream end of the first combustion section. As seen in Figure 1, second cooling openings 46 are axially-oriented and open toward the upstream end of the burner 12. The openings are circumferentially spaced about the burner proximate the downstream end of first combustion section 18 and communicate inlet air from annular conduit 26 to the upstream end of second combustion section 20. Second cooling openings 46 are disposed to introduce approximately 8% of inlet air into second combustion chamger 20 in a swirling pattern which generates an annular cooling layer at the upstream end of section 20 which subsequently mixes with the second primary portion. The annular cooling layer does not extend to the downstream end of second combustion section 20.

The combustor of the invention also includes a dilution means for introducing a dilution portion of the inlet air into the exhaust section to cool the exhaust gas from the burner. As seen in Figure 1, dilution means comprises a plurality of radially oriented dilution openings 48 which receive approximately 44% of inlet air from annular conduit 26 and direct the inlet air into exhaust section 22 of burner 12 to reduce the average temperature of the exhaust gas prior to reaching the turbine.

The gas turbine engine cobustors of the invention are capable of high temperature operation with low pressure loss and uniform exhaust temperature. Where a low air velocity (approximately 150 ft/sec.) and two-stage burning are used, the front end of the burner receives 30% of the inlet air providing a fuel-air ratio of 8.5 to 10% which is above stoichiometric, resulting in a low flame temperature. This low flame temperature and two-stage burning provides low heat transfer to the burner wall which is then cooled by convection cooling through the reverse flow of inlet air. The overall structure provides a temperature distribution factor of about 0.07 to 0.12. The temperature distribution factor is defined as maximum temperature minus average temperature divided by average temperature minus inlet temperature.

It will be apparent to those skilled in the art that various modifications and variations could be made in the combustor of the invention without departing from the scope or spirit of the invention.

CLAIMS

1. A combustor for a gas turbine engine, comprising:

(a) a burner (12) defining an axial fluid-flow path between upstream and downstream ends (14,16) thereof, said burner (12) including a first combustion section (18) proximate said upstream end (14), a second combustion section (20) axially downstream of said first combustion section (18) and an exhaust section (22) proximate said downstream end (16);

(b) a burner casing (24) coaxially surrounding said burner (12) and defining an annular conduit (26) for flow of inlet air from downstream to upstream ends (16,14) of said burner (12), said inlet air flow convectionally cooling said burner;

(c) means (30) at the upstream end (14) of said burner (12) for introducing fuel into said first combustion section;

(d) first primary means (40) for introducing a first primary portion of said inlet air into said first combustion section (18) to generate a combustible fuel-air mixture therein;

(e) first cooling means (42) for introducing a first cooling portion of said inlet air into said first combustion section (18) to generate a swirling flow of first cooling air therein, said swirling flow of first cooling air substantially mixing with said first primary portion downstream in said first combustion section (18);

(f) second primary means (44) for introducing a second primary portion of said inlet air into said second combustion section (20) to generate a combustible fuel-air mixture therein;

(g) second cooling means (46) for introducing a second cooling portion of said inlet air into said second combustion section (20) to generate a swirling flow of second cooling air therein, said swirling flow of second cooling air substantially mixing with said second primary portion downstream in said second combustion section (20); and

(h) dilution means (48) for introducing a dilution portion of said inlet air into said exhaust section (22) to cool the exhaust gas of said burner (12).

2. A combustor according to claim 1, characterised in that the swirling flow of first cooling air creates an annular cooling layer proximate the upstream end (14) of the first combustion section (18), and the swirling flow of second cooling air creates an annular cooling layer proximate the upstream end of the second combustion section (20).

3. A combustor according to claim 2, characterised in that the first primary portion is approximately 18% of said inlet air, said first cooling portion is approximately 12% of said inlet air, said second primary portion is approximately 18% of said inlet air, said second cooling portion is approximately 8% of said inlet air, and said dilution portion is approximately 44% of said inlet air.

4. A combustor according to claim 1, characterised in that the first cooling means (42) introduces about 12% of said inlet air into said first combustion section to generate a swirling flow of first cooling air therein, said swirling flow of first cooling air substantially mixing with inlet air from said first primary means (40) after cooling the upstream end of said first combustion section (18); the second primary means (44) introduces about 18% of said air into said second combustion section (20) to generate a combustible fuel-air mixture therein; the second cooling means (46) introduces about 8% of said inlet air into said second combustion section (20) to generate a swirling flow of second cooling air therein, said swirling flow of second cooling air substantially mixing with inlet air from said second primary means (44) after cooling the upstream end of said second combustion section (20) and the dilution means (48) introduces about 44% of the inlet air into said exhaust section (22) to cool the exhaust gas of said burner (12).

5. A combustor according to claim 4, characterised in that the first primary means comprises a plurality of first primary openings (40) in the upstream end (14) of said burner (12) disposed around said fuel introducing means (30) communicating inlet air from said annular conduit (26) to said first combustion section (18).

6. A combustor according to claim 5, characterised in that the first cooling means comprises a plurality of first cooling openings (42) in the upstream end (14) of said burner (12) disposed in an annular array radially outward of said first primary openings (40).

7. A combustor according to claim 4, characterised in that the second primary means comprises a plurality of radially-oriented second primary openings (44) circumferentially spaced about said burner (12) proximate the downstream end of said first combustion section (18) communicating inlet air from said annular conduit (26) to the upstream end of said second combustion section (20).

8. A combustor according to claim 4, characterised in that second cooling means comprises a plurality of axially-oriented second cooling openings (46) circumferentially spaced about said burner (12) proximate the downstream end of said first combustion section (18), communicating inlet air from said annular conduit (26) to the upstream end of said second combustion section (20), each said second cooling opening (46) having an entrance directed toward the upstream end (14) of said burner (12).

9. A combustor according to claim 4, characterised in that dilution means comprises a plurality of radially-oriented dilution openings (48) circumferentially spaced about said burner (12) proximate the downstream end of said second combustion section (20) communicating inlet air from said annular conduit (26) to said exhaust section (22).

FIG. 1.

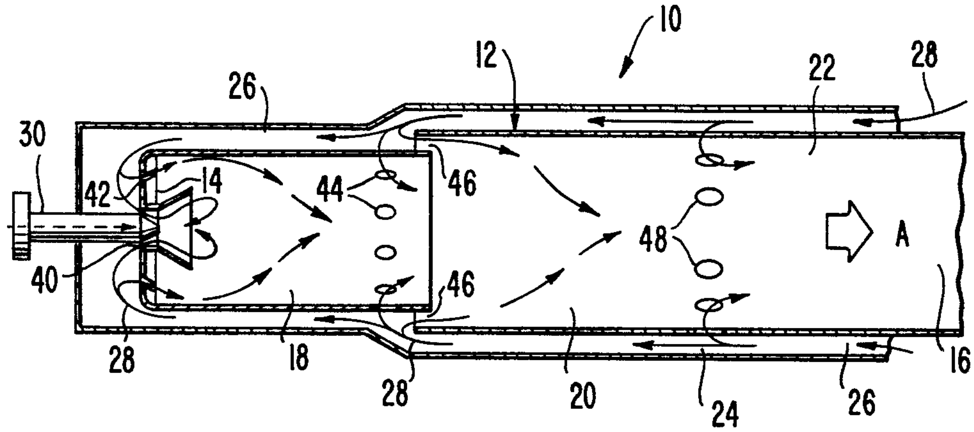

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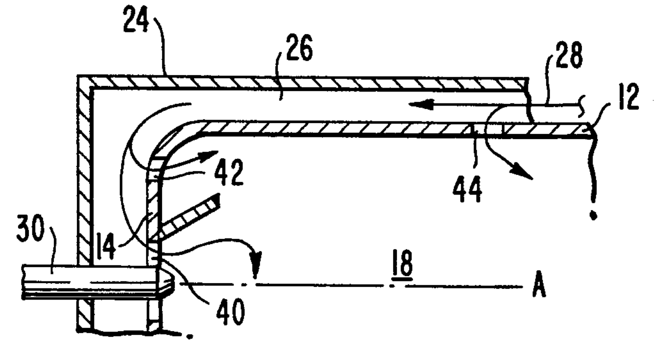
FIG. 2.



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