AXIALLY STAGED PREMIXED COMBUSTION CHAMBER

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ABSTRACT
A combustor for a gas turbine includes a plurality of radially outer nozzles arranged in an annular array, each of the radially outer nozzles having an outlet end located to supply fuel and/or air to a first combustion chamber. A center nozzle has an outlet end located axially upstream of the outlet ends of the radially outer nozzles, and is configured and arranged to supply fuel and air to a second combustion chamber axially upstream of the first combustion chamber. The second combustion chamber opens into the first combustion chamber and has a length sufficient to maintain a center nozzle flame confined to the second combustion chamber.
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[0001] This invention relates to gas turbine technology and, more specifically, to an axially staged gas turbine combustor nozzle configuration that promotes enhanced CO burn-off.

BACKGROUND OF THE INVENTION

[0002] Currently, there is a limit to an otherwise desirable reduction in the exit temperature of combustion gases due to the amount of CO contained in the combustion gases. In other words, combustor exit temperature must be kept relatively high in order to ensure CO burn-off to meet required emission levels for CO. In order to keep the combustor exit temperature high enough to maintain low CO levels at low- or no-load conditions, the customer must either shut the turbine down or keep the turbine “on-line”, even during periods of low power requirements, thus increasing the amount of fuel consumed.

[0003] There is a need, therefore, for a mechanism by which the amount of CO generated by combustion in the gas turbine can be reduced so that the customers’ shutdown capability can be enhanced. More specifically if CO levels could be reduced with the combustor at low- or no-load conditions, customers would use less fuel during times of reduced electrical demand. This, in turn, would result in direct fuel savings, but without having to shut down the turbine and then restart when demand returns, thus producing reliability enhancements as well.

BRIEF DESCRIPTION OF THE INVENTION

[0004] In a first exemplary but nonlimiting embodiment, the invention relates to a combustor for a gas turbine comprising a plurality of radially outer nozzles arranged in a substantially annular array, each of the radially outer nozzles having an outlet end located to supply fuel and/or air to a first combustion chamber; at least a center nozzle having an outlet end located axially upstream of the outlet ends of the radially outer nozzles, configured and arranged to supply fuel and air to a second combustion chamber axially upstream of the first combustion chamber, the second combustion chamber opening into the first combustion chamber and having a length sufficient to maintain a center nozzle flame confined to the second combustion chamber.

[0005] In another exemplary aspect, the invention relates to a combustor for a gas turbine comprising a plurality of nozzles arranged in a substantially annular array, each of the nozzles having an outlet end located to supply fuel and/or air to a first combustion chamber; a center nozzle and at least one of the plurality of nozzles having outlet ends located axially upstream of the outlet ends of remaining ones of the plurality of nozzles, configured and arranged to supply fuel and air to a second combustion chamber axially upstream of the first combustion chamber, the second primary combustion chamber opening into the first combustion chamber and having a length sufficient to maintain a center nozzle flame and a flame of the at least one of the plurality of nozzles confined to the second combustion chamber.

[0006] In still another exemplary aspect, the invention provides a method of operating a gas turbine having at least one combustor supplied with fuel and/or air through a plurality of nozzles including an outer array of nozzles surrounding a center nozzle, the method comprising (a) at no- or low-load conditions, supplying fuel and air to the center nozzle and air only to the outer array of nozzles while isolating a flame generated by the center nozzle from air flowing through the outer array of nozzles; and (b) at higher load conditions, supplying a fuel/air mixture through both the outer array of nozzles and the center nozzle such that flames generated by the outer array of nozzles are maintained in a first combustion chamber and a flame generated by the center nozzle is maintained in a second combustion chamber upstream of the first combustion chamber.

[0007] The invention will now be described in more detail in connection with the drawings identified below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a cross section through a gas turbine combustor in accordance with a first exemplary but nonlimiting embodiment of the invention;

[0009] FIG. 2 is a partial, enlarged perspective view of the combustor shown in FIG. 1;

[0010] FIG. 3 is a partially sectioned perspective view of the combustor shown in FIG. 2; and

[0011] FIG. 4 is a schematic diagram of a combustor configuration in accordance with another exemplary but nonlimiting embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0012] With reference now to FIGS. 1-3, a gas turbine combustor 10 in accordance with an exemplary but nonlimiting embodiment of the invention is illustrated. It will be understood that the combustor 10 is typically combined with several other similar combustors arranged in an annular array about the gas turbine casing, each combustor supplying combustion gases to the first stage of the turbine. Each combustor 10 is supplied with air from a compressor (not shown). The compressor air is reverse-flowed (as indicated by the flow arrows), into an annular passage 12 located between the radially inner and axially-aligned transition piece 14 and combustion chamber liner 16 on the one hand, and the radially outer, axially-aligned flow sleeves 18 and 20 on the other. The compressor air flows into the passage 12 through impingement cooling holes 22, 24 in the respective flow sleeves 18 and 20, thus also providing cooling to the transition piece and combustor liner, before reversing flow at the inlet end of the combustor. Generally, and under certain operating conditions, the air will flow into air injectors associated with each of a plurality of six radially outer nozzles 26 and a center nozzle 28 (the number of nozzles in the combustor typically varies between 6 and 8) where it pre-mixes with fuel supplied to the nozzles via the combustor end cover 30. The air/fuel mixture from the radially outer nozzles 28 is injected into the burning zone, or main combustion chamber 32. Ignition is achieved by spark plugs (not shown) in conjunction with crossfire tubes (also not shown) that connect adjacent combustors. Hot combustion gases flow from the combustion chamber 32 into the transition piece 14 and then to the first stage of the gas turbine, represented by a single nozzle blade 34. To this point, the combustor as described is generally well known, and the invention here relates to the location of the center nozzle 28 relative to the radially outer nozzles 26 and 30, and to the establishment of a second (or primary) combustion chamber 36 upstream of the first (or main) combustion chamber 32.
More specifically, and with continuing reference especially to FIGS. 2 and 3, the center nozzle 28 is recessed in an upstream direction (relative to a flow direction of combustion gases from left to right in the various FIGS.) In other words, the center nozzle 28 is located axially behind the outlets of the radially outer surrounding nozzles 26. A combustor cap 38 supports the outlet ends of the outer nozzles, but is configured and mounted so as to allow compressor air to flow between the cap and the casing wall 40 (FIG. 1). A substantially cylindrical tubular member 42 extends rearwardly from the cap 38 to the outlet end of the center nozzle 28, thus forming the primary combustion chamber 36 which opens into the main combustion chamber 32 at the forwardmost point 44 of the cap 38. The length of the chamber 36 is determined so as to be sufficient to allow complete combustion of CO while protecting the center nozzle flame from the surrounding cold air flowing into the main chamber 32 via the radially outer nozzles 26.

Fuel is supplied to the radially outer nozzle tubes (two shown at 46 (FIG. 1) and to the center nozzle tube 48 through the end cover 30 as noted above, while air is supplied to the radially outer nozzles at conventionally-configured premix swirler inlets 50 (two shown in FIG. 3), and to the center nozzle 28 through premix swirler inlet via apertures 52 in the radial vane 54.

At low-load regimes down to full-speed no-load (FSNL), fuel is supplied only to the center nozzle 28, while air flows through the radially outer nozzles 26. By confining the center nozzle flame to the primary combustion chamber 36, it is protected from the cold air supplied through the radially outer nozzles 26 and thus not subject to an undesirable temperature drop. As a result, by maintaining the center nozzle flame at a high temperature, and with sufficient fuel volume to the center nozzle 28, the center nozzle flame will burn off the resident CO. The reduction in CO levels will, in turn, allow the turbine to turn the gas turbine down even further in low load reduced fuel consumption, when power requirements are low, with attendant.

As loading is increased, there comes a point when the amount of fuel required for combustion is greater than can be accommodated by the center nozzle 28. The radially outer nozzles 26 are then brought on board, with fuel supplied to the radially outer nozzles by mixing with combustion air supplied by the compressor as described above. The combustion flames associated with the outer nozzles 26 are anchored downstream of the primary combustion chamber 36, within the main combustion chamber 32. The radially outer nozzles 26 may be “lit” or ignited simultaneously, or in some predetermined sequence (or simultaneously in groups of 2 or three, for example) as dictated by combusting optimization for specific combustor applications.

In any event, at the FSNL, the center nozzle flame remains anchored in the primary combustion chamber 36 while the outer nozzle flames remain anchored in the main combustion chamber 32, downstream of the primary combustion chamber 36. Because the tubular member 42 defining the primary combustion chamber 36 is exposed directly to the center nozzle flame, it must be cooled by any suitable means such as, for example, application of a thermal barrier coating, impingement cooling, the addition of turbulators, or any combination of the above.

In an optimized application of the invention to a particular turbine model, one third (1/3) of the combustion air will flow through the center nozzle, and two thirds (2/3) through the array of outer nozzles, with a phi ratio of approximately 0.6 (phi is an equivalence ratio defined as the ratio of the actual fuel/air ratio to the stoichiometric value). Typical phi values range from 0.50 to 0.65.

In an alternative operational mode at FSNL, the flame in the center nozzle 28 may be extinguished for a relatively short time, and then resupplied with fuel such that the flame re-ignites (and is maintained) downstream of the primary combustion chamber 36. By reigniting the center nozzle flame in the main combustion chamber 40 and keeping it out of the primary combustion chamber 36, the temperature of the tubular member 42 will be cooler, and the mixing zone for the fuel and air supplied to the center nozzle 28 is extended, resulting in better mixing and in lower NOx emissions. In this alternative FSNL operational mode, it may be advantageous to have the wall of the tubular member 42 taper inwardly in the downstream direction. The higher velocity of the fuel/air mixture moving through the reduced cross section would prevent the center nozzle flame from moving upstream, back into the primary combustion chamber. Note that in the event it is decided to reignite the flame within the primary combustion chamber 36, it is necessary to provide a spark plug or other igniter in the chamber.

In still another exemplary but nonlimiting embodiment, more than one nozzle can be protected from the cold air flowing through the surrounding or adjacent nozzles at FSNL. For example, a center nozzle and one or two other nozzles in the outer array could be recessed in the same manner as described above in connection with the center nozzle 28. In addition, the one or two additional nozzles could be located in a single oblong, oval or other shape combustion chamber, i.e., the chamber shape would be dictated by the number and location of the recessed nozzles. One such arrangement is shown in FIG. 4 where a center nozzle 128 and one of a surrounding array of radially outer nozzles 126 is recessed within a second combustion chamber 136 defined by an oblong tubular member 142.

This developed multi-stage combustor is thus capable of isolating fueled nozzles (for example, the center nozzle 28) reacting flames from excessively cold surrounding air exiting adjacent unfueled nozzles (for example, the radially outer nozzles 26 at part-or no-load regimes by establishing a combustion zone in a recessed combustion chamber (the primary combustion chamber 36) for complete CO burnout at the end of that chamber.

What is claimed is:
1. A combustor for a gas turbine comprising: a plurality of radially outer nozzles arranged in a substantially annular array, each of said radially outer nozzles having an outlet end located to supply fuel and/or air to a first combustion chamber; at least a center nozzle having an outlet end located axially upstream of said outlet ends of said radially outer nozzles, configured and arranged to supply fuel and air to a second combustion chamber axially upstream of said first combustion chamber, said second combustion chamber opening into said first combustion chamber and having a length sufficient to maintain a center nozzle flame confined to said second combustion chamber.
2. The combustor of claim 1 wherein said outlet ends of said radially outer nozzles are supported in an annular plate, and wherein a tubular member defining said second combustion chamber extends from said annular plate in an upstream direction.
3. The combustor of claim 1 wherein means are provided for supplying either air alone, or air and fuel to said plurality radially outer nozzles.

4. The combustor of claim 3 wherein means are provided for supplying fuel and air to said center nozzle.

5. The combustor of claim 1 wherein, in addition to said center nozzle, one or more of said plurality of radially outer nozzles have outlet ends upstream of remaining ones of said plurality of radially outer nozzles.

6. The combustor of claim 5 wherein said one or more of said plurality of radially outer nozzles are configured and arranged to supply fuel and air to said second combustion chamber.

7. A combustor for a gas turbine comprising:
   a plurality of nozzles arranged in a substantially annular array, each of said nozzles having an outlet end located to supply fuel and/or air to the first combustion chamber; a center nozzle and at least one of said plurality of nozzles having outlet ends located axially upstream of said outlet ends of remaining ones of said plurality of nozzles, configured and arranged to supply fuel and air to a second combustion chamber axially upstream of said first combustion chamber, said second combustion chamber opening into said first combustion chambers and having a length sufficient to maintain a center nozzle flame and a flame of said at least one of said plurality of nozzles confined to said second combustion chamber.

8. The combustor of claim 7 wherein said outlet ends of said radially outer nozzles except for said at least one of said plurality of nozzles are supported in an annular plate, and wherein a tubular member defining said second combustion chamber extends from said annular plate in an upstream direction.

9. The combustor of claim 7 wherein means are provided for supplying either air alone, or air and fuel, to said plurality of radially outer nozzles.

10. The combustor of claim 9 wherein means are provided for supplying fuel and air to said center nozzle.

11. A method of operating a gas turbine having at least one combustor supplied with fuel and/or air through a plurality of nozzles including an outer array of nozzles surrounding a center nozzle, the method comprising:
   a. at no- or low-load conditions, supplying fuel and air to said center nozzle and air only to said outer array of nozzles while isolating a flame generated by said center nozzle from air flowing through said outer array of nozzles; and
   b. at higher load conditions, supplying a fuel/air mixture through both said outer array of nozzles and said center nozzle such that flames generated by said outer array of nozzles are maintained in a first combustion chamber and a flame generated by said center nozzle is maintained in a second combustion chamber upstream of said first combustion chamber.

12. The method of claim 11 further comprising:
   c. extinguishing said flame generated by said center nozzle; and
   d. reigniting a new flame generated by said center nozzle, with said new flame anchored in said first combustion chamber.

13. The method of claim 11 wherein said first combustion chamber has a length sufficient to burn off CO at low or no-load levels.

14. The method of claim 11 including cooling a tubular member defining said second combustion chamber.

15. The method of claim 14 wherein said cooling is carried out by anyone of impingement cooling, thermal barrier coating, turbulators or any combination thereof.

16. The method of claim 11 wherein step (a) is carried out with respect to at least one additional nozzle in said outer array of nozzles.

17. The method of claim 11 wherein step (a) is carried out at full speed/no load conditions.

18. The method of claim 11 wherein step (b) is carried out at full speed/no load conditions.

19. The method of claim 17 wherein the method of claim 11 wherein step (b) is carried out at full speed/no load conditions.

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