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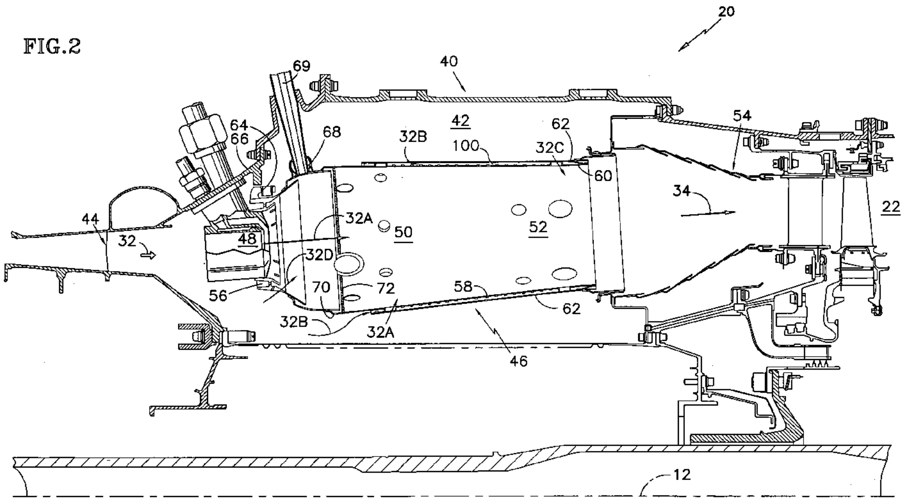
FIG.2



(57) Abstract: Provided are gas turbine engines 10, combustion chambers 46 and methods of operation for reducing NOx and CO emissions in aerospace and industrial applications. An upstream compressor 18 provides pressurized air 32 to a combustion chamber having an inner liner 58 and an outer shroud 62 circumscribing a portion of the inner liner 58. The inner liner 58 having a wall 74 with an inwardly facing hot side 76 and an outwardly facing cold side 78. The shroud 62 is spaced from the inner liner 58, forming an annulus 100 for accepting a pressurized air stream 32B therein. Heat transfer features 82, disposed on the cold side 78, exchange heat from the liner wall 74 to the air stream 32B. Methods of operation include introducing fuel and air inside a liner wall 74 without premixing, and producing combustion products without introducing any additional pressurized air adjacent the hot side 76.

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A GAS TURBINE ENGINE AND METHOD OF OPERATION

BACKGROUND OF THE INVENTION

(1) FIELD OF THE INVENTION

The present invention generally relates to a gas turbine engine and more specifically to a combustion chamber of the engine with reduced emissions.

(2) DESCRIPTION OF THE RELATED ART

Gas turbine engines operate according to a continuous-flow, Brayton cycle. A compressor section pressurizes an ambient air stream, fuel is added and the mixture is burned in a central combustor section. The combustion products expand through a turbine section where bladed rotors convert heat energy from the combustion products into mechanical energy for rotating one or more centrally mounted shafts. The shafts, in turn, drive the forward compressor section, thus continuing the cycle. Gas turbine engines are compact and powerful power plants, making them suitable for powering aircraft, heavy equipment, ships and electrical power generators. In power generating applications, the combustion products also drive a separate power turbine attached to an electrical generator.

Most power turbine applications provide base load power and peak power during high demand periods only. Other applications include a more continuous mode of operation such as a means to power natural gas pipeline pumping and powering military and commercial ships. Because most power turbine applications are land-based installations, the exhaust emissions typically require treatment to meet government, state and local clean air standards for unburned hydrocarbon (HC), oxides of nitrogen (NOx), carbon monoxide (CO) and smoke or airborn particulate. Most permanent installations include large stacks to redirect the exhaust stream upward while simultaneously providing treatment to lower emissions. Today, exhaust gases are treated with selective catalytic converters and other methods of exhaust clean up down stream of the engine. As the worldwide demand for electrical power continues to rise, air emissions standards are becoming ever more paramount and stringent.

During the combustion process, different types of emissions are created at various times and areas in the combustor. NOx typically forms at the forward region, in the hottest area of the combustor where the fuel and combustion air mixture ignites to form the combustion flame. The CO emissions form as the combustion reaction propagates axially rearward down the axial length of the combustion chamber. More complete combustion reduces the CO emissions produced as the CO is converted to CO_2 by hotter combustion and/or longer residence time.

One method of NOx reduction involves the injection of moisture such as water (H_2O) or steam into land-based turbines. The H_2O or steam may be injected at locations from the engine inlet to the combustor. Typical combustor locations include the fuel nozzle or injector and various locations along the combustor wall. The moisture quenches the combustion flame temperature and significantly reduces the formation of NOx.

Another method of reducing NOx formation in land-based or aero turbines is known as 'Dry Low NOx' (DLN) or 'Dry Low Emissions' (DLE) combustion. With DLN/DLE combustion, a lean combustion mixture produces a lower combustion flame temperature. Yet another method of reducing NOx formation in land-based or aero turbines is to inject additional compressor air transversely into the combustion flame to quench the combustion flame temperature, thus reducing the formation of NOx. However, by reducing the combustion flame temperature using any of these methods, the level of CO emissions may actually increase due to the lower flame temperatures.

During engine operation, combustion chambers contain flame temperatures in excess of about 3000 degrees Fahrenheit (1649 degrees Celsius). In order to operate for the number of years necessary to be economically viable, metal combustion chamber wall temperatures must not exceed about 1700 degrees Fahrenheit (927 degrees Celsius). Routinely subjecting a combustion chamber to temperatures above about 1700 degrees Fahrenheit (927 degrees Celsius) will eventually weaken the material, leading to oxidation, loss of material and part replacement.

What is presently needed is a combustion chamber for reducing both NOx and CO emissions, without negatively affecting component durability or the operational efficiencies of the other gas turbine engine sections.

BRIEF SUMMARY OF THE INVENTION

Provided are gas turbine engines 10, combustion chambers 46 and methods of operation for reducing NOx and CO emissions in aerospace and industrial applications. An upstream compressor 18 provides pressurized air 32 to a combustion chamber having an inner liner 58 and an outer shroud 62 circumscribing a portion of the inner liner 58. The inner liner 58 having a wall 74 with an inwardly facing hot side 76 and an outwardly facing cold side 78. The shroud 62 is spaced from the inner liner 58, forming an annulus 100 for accepting a pressurized air stream 32B therein. Heat transfer features 82, disposed on the cold side 78, exchange heat from the liner wall 74 to the air stream 32B.

Methods of operation include introducing fuel and air inside a liner wall 74 without premixing, and producing combustion products without introducing any additional pressurized air adjacent the hot side 76.

These and other objects, features and advantages of the present invention will become apparent in view of the following detailed description and accompanying figures illustrating various embodiments, where corresponding identifiers represent like features between the various figures.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a segmented cross section of a land-based gas turbine engine;

Figure 2 is a cross section of a combustor of the gas turbine engine of Figure 1 according to an embodiment of the present invention, with the lower half details removed for clarity;

Figure 3 is a perspective view of a combustion chamber of the combustor of Figure 2;

Figure 4 is a cross section of an aft liner to shroud seal of the combustion chamber of Figure 3 taken along line 4-4;

Figure 5 is a cross section of the a forward liner to shroud seal of the combustion chamber of Figure 3 taken along line 5-5;

Figure 6 is a cross section of a liner boss of the combustion chamber of Figure 3 taken along line 6-6;

Figure 7 is a perspective view of the combustion chamber of Figure 3 with the outer shroud partially removed to illustrate internal features;

Figure 8 is a perspective cross section of a tab of the combustion chamber of Figure 7 taken along line 8-8; and

Figure 9 is a chart comparing the CO and NOx characteristics of a conventional, baseline combustion chamber with those of the present, low emissions combustion chamber.

DETAILED DESCRIPTION OF THE INVENTION

An exemplary industrial gas turbine engine 10 is circumferentially disposed about a central, longitudinal axis or axial centerline 12 as illustrated in Figure 1. The engine 10 includes in series order from front to rear, low and high pressure compressor sections 16 and 18, a central combustor section 20 and high and low pressure turbine sections 22 and 24. In some examples, a free turbine section 26 is disposed aft of the low pressure turbine 24. This application also extends to aero engines with a fan or gear driven fan, and engines with more or fewer sections than illustrated.

As is well known in the art of gas turbines, incoming ambient air 30 becomes pressurized air 32 in the compressors 16 and 18. Fuel mixes with the pressurized air 32 in the combustor section 20, where it is burned. Once burned, combustion products 34 expand through turbine sections 22, 24 and power turbine 26. Turbine sections 22 and 24 drive high and low rotor shafts 36 and 38 respectively, which rotate in response to the combustion products and thus the attached compressor sections 18, 16. Free turbine section 26 may, for example, drive an electrical generator, pump, or gearbox (not shown).

It is understood that Figure 1 provides a basic understanding and overview of the various sections and the basic operation of an industrial gas turbine engine. It will become apparent to those skilled in the art that the present application is applicable to all types of gas turbine engines, including those with aerospace applications.

Referring now to the combustor module 20 of Figure 2, a combustor case 40 forms an annular pressurized air passage 42, which receives a portion of the pressurized air 32 via a diffuser 44. Distributed circumferentially about the centerline 12 is an array of approximately cylindrical combustion chambers 46, also known as combustor cans. A fuel nozzle 48 delivers natural gas, diesel, home heating oil, aviation fuel, bio fuels or other fuels to each chamber 46. Water or steam may also be introduced through the fuel nozzle 48, or other locations upstream of, or within the combustion chambers 46. The fuel burns within each chamber 46 in rich and lean combustion zones 50, 52. The combustion products 34 then exit the chamber 46 through a louvered transition duct 54 to the high pressure turbine module 22.

Each combustion chamber 46 broadly comprises a forward scoop 56, an inner liner 58, an aft ring 60 and an outer shroud 62. In one example, a front attachment 64 is affixed to the scoop 56 and secures each combustion chamber 46 to a diffuser case 66. The aft ring 60 fits within the transition duct 54 and secures the combustion chamber 46 at the rear. At least one of the chambers 46 may include an igniter retaining provision 68, which retains an igniter 69 for initiating a flame during start up. Transfer tubes (Figure 7) may join adjacent chambers 46, allowing the combustion flame to propagate between chambers.

One or more stepped louvers 70 are arranged between the scoop 56 and the inner liner 58. The scoop 56 is formed of a high strength material. Preferably, the rearmost louver 70 has a shape that closely resembles the inner liner 58 to which it is joined.

The rear louver 70 is joined to the inner liner 58 at a butt-type, forward joint 72. Although resistance welding, flash butt welding, laser welding, brazing or other methods may be used, the forward joint 72 is preferably created via a fusion welding process. The fusion welded joint 72 can be formed manually or robotically. By using a fusion weld process to form the joint 72, nondestructive inspection techniques such as x-ray, fluorescent penetrant, ultrasonic or similar techniques are used to ensure joint 72 integrity. In other examples, the rear louver 70 is integrally formed with the inner liner 58 and joined to an upstream louver 70 using a lap style joint (not illustrated). A lap style joint requires samples to be removed destructively and inspected microscopically to ensure joint integrity. The lap joint inspection process adds an additional overhead cost to each of the combustion chambers 46.

Referring now to Figures 3-7, the shape of the inner liner 58 is substantially cylindrical. An inner liner wall 74 has a radial thickness and is defined by an internal, hot side 76 (facing the rich and lean combustion zones 50, 52) and an oppositely faced, external, cold side 78. The surface of the hot side 76 is relatively featureless, and the surface of the external cold side78 has a scalloped flange 80, heat transfer features 82 and bosses 84. The scalloped flange 80 is located proximate the forward joint 72, and extends radially outwardly from the cold side 78. The flange 80 comprises a plurality of circumferentially spaced scallops around the outer radial edge for introducing air.

A plurality of heat transfer features 82 create an interrupted topology on the surface of the cold side 78. The features 82 preferably extend radially outwardly from the cold side 78; however, other heat transfer features such as voids or dimples in the cold side 78 and axial fins are also contemplated. For example, a plurality of pedestals and/or dimples of various shapes and sizes may be arranged about the cold side 78. While feature 82 shapes such as spherical, square or other shapes may be also used, only cylindrical shaped pedestals of varying spacing are shown for brevity.. The features 82 are sized and arranged to tailor the transfer of heat from the liner wall 74 to the cooling air 32B in the annulus 100 between the liner hot side 76 and shroud 62. The features 82 may be oriented in patterns such as axial rows or circumferential rows or can be non-linear or the patterns may be completely variable. In one example, the pattern orientation varies in the axial direction.

The rich combustion zone 50 typically operates at a higher temperature than the lean zone 52, so the heat transfer features 82 are sized and arranged to remove a greater amount of localized heat. In the rich and lean zones 50, 52, the pattern is tailored to remove an appropriate amount of heat. As shown in the example, the features 82 vary in size and spacing in order to tailor the heat transfer capability. By tailoring the size and pattern of the heat transfer features 82, a varying amount of heat is removed from the liner wall 74 depending upon axial and circumferential location. Localized hot spots may require more heat transfer features 82 than cooler areas. The result of a varying pattern of features 82 is a substantially constant temperature profile about the inner liner wall 74.

As best illustrated in Figures 4-6, bosses 84 are spaced about the inner liner 58 at various axial and circumferential locations. In one example, a boss 84 is cylindrical shaped and includes a boss wall 86, bounded by a boss outer surface 88 and a boss bore 90. Each boss 84 extends radially outwardly from the cold side 78 with the bore 90 penetrating through the boss 84 and the inner liner wall 74. The boss wall 86 contains a radially outer sealing surface 92 that may be flat or arcuate. Preferably, the shape of the sealing surface 92 is defined by a radius extending from a longitudinal, combustion chamber axis 94 to match the shape of the outer shroud 62. The shape of the sealing surface 92 may or may not be constant in the axial direction. Further details of the sealing surfaces 92 and their function are discussed later.

The inner liner 58 is preferably formed from a high strength, high temperature capability material using an investment casting process. For example, die casting, sand casting, spin casting, chemical milling, conventional milling or other methods can also be used to form the liner. Although the scalloped flange 80, heat transfer features 82 and bosses 84 may be formed separately and affixed to the inner liner via brazing, welding or machining for example, they are preferably formed with the inner liner 74 during manufacture.

An aft ring 60 can be affixed to the inner liner 58 at an aft joint 96. The aft joint 96 is preferably a butt type joint and is similar in construction to the forward joint 72 discussed earlier. The aft ring 60 is formed of a high strength sheet material by spinning, press forming, joining or other suitable methods.

Referring to the embodiment of Figure 8, a plurality of spaced tabs 98 extend radially outwardly from the ring 60 proximate the aft joint 96. A first end of the tabs 98 is affixed to the aft ring 60 and a second end is affixed to the shroud 62 by resistance welding or similar joining methods. The tabs 98 effectively space the shroud 62 from the inner liner 58 and affix the shroud 62 to the aft ring 60 at the aft end of the combustion chamber 46. In other embodiments, the shroud 62 is affixed to the inner liner 74 at a forward or central location.

The shroud 62 is approximately cylindrical shaped and circumscribes a portion of the inner liner 58, defining an annulus 100 therebetween. The shroud 62 is formed of a high temperature capability material. A number of apertures 102 penetrate the shroud 62 and are spaced about the shroud 62 as illustrated in Figure 4. Some apertures 102 align with and correspond to the boss bores 90 while others do not. The function of the apertures 102 is determined by location. Apertures 102 corresponding to the boss bores 90 and disposed near the forward end of the shroud 62 introduce a portion of compressor air 32A to the rich combustion zone 50. Apertures 102 corresponding to the boss bores 90 and disposed near the aft end of the shroud 62 introduce compressor air 32C into the lean combustion zone 52. Apertures 102 that do not align with or correspond to the boss bores 90 introduce compressor air 32B into the annulus 100.

Since the shroud 62 is affixed to the aft ring 60 via the plurality of tabs 98, it is constrained from rearward axial movement. There is slight relative axial growth between the shroud 62 and the inner liner 58 due to thermal expansion differences, so the shroud 62 is not constrained proximate the forward joint 72. As the shroud 62 expands axially forward, it slides along the scalloped flange 80 and the sealing surface 92 of corresponding bosses 84.

As described earlier, a number of the shroud apertures 102 communicate with the boss bores 90 in the inner liner 58. The shroud apertures 102 that communicate with the boss bores 90 are slightly larger than the boss bores 90 while also being slightly smaller than the boss outer surfaces 88. This overlap allows the boss sealing surface 92 to seat against the shroud 62, forming a substantial seal between the inner liner 58 and the shroud 62. Note that it is preferable for the ratio of shroud aperture 102 diameter to boss bore 90 diameter to increase the farther the boss 84 is away from the aft ring 60. This accommodates the greater axial displacement of the shroud 62 proximate the forward joint 72. The size and location of the shroud apertures 102 and boss bores 90 and boss outer walls 88 are defined such that during engine operation the edges of the shroud apertures 102 do not block the boss bores 90 and also do not allow a leakage path to form between the shroud aperture 102 edges and the boss outer walls 88.

The radial height of each boss 84 provides a minimal clearance between the sealing surface 92 and the outer shroud 62 for enabling cold assembly in an engine. At operating temperatures, the sealing surface 92 moves outward radially and seats against the outer shroud 62 to form a substantial seal. The radial growth is determined to provide a substantial seal at operating temperatures and relative axial movement between the inner liner 58 and the outer shroud 62 at lower temperatures.

A diffusion combustor system is defined broadly as a system where gaseous or liquid fuel is introduced into the combustion chamber without premixing in the pressurized air (also known as oxidizer air stream) prior to combustion. No additional pressurized air enters the chamber to film cool the hot side 76 of the inner liner wall 74. Moisture in the form of water or steam may also be introduced upstream of the combustor 20, through the fuel nozzle 48, or along the liner wall 74.

Referring back to Figure 2, a method of operation of the gas turbine engine and low emissions combustor 20 is described in greater detail. A fuel nozzle 48 injects fuel, in the form of a liquid or a gas and in some examples fuel and moisture, into the combustion chamber 46. An igniter 69 initially lights the mixture in rich combustion zone 50 and, once lit, the flame propagates between adjacent combustion chambers 46 via cross over tubes (not shown).

The low emissions combustor 20 uses the pressurized compressor air 32 exiting the diffuser 44 for various purposes. A combustion portion of the air 32A enters the rich combustion zone 50 axially through the fuel nozzle 48, scoop 56, and transversely through a forward array of boss bores 90 radially spanning the annulus 100 between the wall 74 and outer shroud 62. A cooling portion of the air 32B enters the annulus 100 through the scallops in flange 80 (Figure 8) and through apertures 102. The cooling portion of the air 32B forms a blanket about the inner liner wall 74, eventually exiting the annulus 100 between the aft tabs 98 (Figure 8). Again, note that the cooling portion of the air 32B remains in the annulus 100 and does not enter the rich or lean combustion zones 50, 52. A diffusion portion of the air 32C enters the lean combustion zone 52 transversely though an aft array of boss bores 90. The diffusion portion 32C conditions the radial profile and circumferential pattern of the combustion products for entry into the turbine 22. A film portion of the air 32D enters upstream of the inner liner 74 and shields the forward louvers 70 from the extreme temperatures proximate the fuel nozzle 48 exit.

The cooling portion of air 32B interacts with the heat transfer features 82 to absorb heat from the liner wall 74. Note that the apertures 102 directing the cooling portion of air 32B into the annulus 100 do not communicate with bosses 84, ensuring the cooling air portion 32B remains external of the rich and lean combustion zones 50, 52. Once in the annulus 100, the cooling air 32B forms a blanket about the liner 58, interacting with the heat transfer features 82. As was noted earlier, the size, shape and pattern of the heat transfer features 82 are tailored to maintain a substantially uniform liner wall 74 temperature.

In conventional, film-cooled combustors, the cooling film adjacent to the hot side 76 of the inner liner wall 74 produces significant amounts of CO. With the combustion chamber 46 of the present invention, more complete combustion results from the absence of a cooling film along the hot side 76. More complete combustion enhances the conversion of CO to CO2 without any increase in NOx emissions. Figure 9 illustrates the dramatic reduction in CO production at any given NOx level of a low emissions combustion chamber when compared to a traditional, film-cooled chamber.

Other alternatives, modifications and variations will become apparent to those skilled in the art having read the foregoing description. The methods are applicable to all diffusion combustor systems, which combust liquid or gaseous fuels that are not premixed with oxidizer air prior to combustion, and inject water or steam without introducing additional air to film cool the combustor. The terms front, forward, fore, rear, rearward and aft relate to standard gas turbine engine nomenclature with the compressor sections being in the front. Accordingly, the invention embraces those alternatives, modifications and variations as fall within the broad scope of the appended claims.

What is claimed is:

CLAIMS

1. A gas turbine engine having reduced emissions comprising:

    a compressor for providing pressurized air; and

    a combustion chamber having;

        an inner liner defining a combustion zone for burning a mixture of fuel and a first portion of the pressurized air, said liner having a wall with a hot side facing the combustion zone and an oppositely faced cold side,

        a shroud affixed to said inner liner and circumscribing a portion of said inner liner, said shroud spaced from said cold side and forming an annulus there between for accepting a second portion of the pressurized air therein, and

        a plurality of heat transfer features disposed on said cold side of said inner liner wall for exchanging heat from said wall to the second portion of the pressurized air.

2. The gas turbine engine set forth in claim 1 wherein said heat transfer features are oriented in a pattern.

3. The combustion chamber set forth in claim 2 wherein the pattern varies.

4. The gas turbine engine set forth in claim 2 wherein at least a portion of said heat transfer features are pedestals.

5. The gas turbine engine set forth in claim 1 further comprising a flange extending from said cold side of said inner liner wall, said flange supporting said shroud proximate a forward joint and allowing the second portion of pressurized air to pass into said annulus.

6. The gas turbine engine set forth in claim 1 further comprising a boss extending from said cold side of said inner liner wall to said shroud, said boss having a bore communicating with an aperture in said shroud.

7. A combustion chamber having reduced emissions comprising:

an inner liner having a wall with an outwardly facing cold side;

a shroud affixed to said inner liner, said shroud circumscribing a portion of said inner liner and being spaced apart from said cold side to form an annulus therebetween; and a plurality of heat transfer features disposed on said cold side of said inner liner wall.

8. The combustion chamber set forth in claim 7 wherein said heat transfer features are oriented in a pattern.

9. The combustion chamber set forth in claim 8 wherein the pattern varies.

10. The combustion chamber set forth in claim 8 wherein at least a portion of said heat transfer features are pedestals.

11. The combustion chamber set forth in claim 7 further comprising a flange extending from said cold side, said flange supporting said shroud proximate a forward joint.

12. The combustion chamber set forth in claim 7 further comprising a boss extending from said cold side of said inner liner wall to said shroud, said boss having a bore communicating with an aperture in said shroud.

13. A method of combusting fuel with reduced emissions comprising the steps of:

a. introducing a fuel inside of a liner wall without premixing in a pressurized air stream prior to ignition;

b. producing a flowing stream of combustion products by igniting the fuel and air; and

c. introducing no additional pressurized air adjacent said liner wall for reducing CO.

14. The method set forth in claim 13 further comprising the step of:

d. introducing moisture into the combustion products for reducing NOx.

15. The method set forth in claim 14 wherein the moisture is introduced upstream of said liner wall.

16. The method set forth in claim 14 wherein the moisture is introduced along said liner wall.

17. A method of reducing emissions in a turbine engine having a combustion chamber defined by a wall having an

inwardly facing hot side and an outwardly facing cold side, said method comprising the steps of:

a. flowing combustion products adjacent said hot side in a downstream direction;

b. flowing air adjacent said cold side in at least partially the downstream direction for reducing CO; and

c. flowing moisture adjacent said hot side and in the downstream direction for reducing NOx.

18. The method as set forth in claim 17 wherein the air flowing adjacent said cold side is constrained radially, forming a blanket.

19. The method as set forth in claim 17 wherein the moisture is introduced upstream of said combustion chamber wall.

20. The method as set forth in claim 17 wherein the moisture is introduced along said combustion chamber wall.

AMENDED CLAIMS
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1. A gas turbine engine having reduced emissions comprising:
   a compressor for providing pressurized air; and
   a combustion chamber having:
      an inner liner defining a combustion zone for burning a mixture of fuel and a first portion of the pressurized air, said liner having a wall with a hot side facing the combustion zone and an oppositely faced cold side;
      a shroud affixed to said inner liner and circumscribing a portion of said inner liner, said shroud spaced from said cold side and forming an annulus there between for accepting a second portion of the pressurized air therein, and wherein at operating temperatures said shroud permits flow of the second portion of the pressurized air in the annulus without entering the combustion zone; and
      a plurality of heat transfer features disposed on said cold side of said inner liner wall for exchanging heat from said wall to the second portion of the pressurized air.

2. The gas turbine engine set forth in claim 1 wherein said heat transfer features are oriented in a pattern.

3. The combustion chamber set forth in claim 2 wherein the pattern varies.

4. The gas turbine engine set forth in claim 2 wherein at least a portion of said heat transfer features are pedestals.

5. The gas turbine engine set forth in claim 1 further comprising a flange extending from said cold side of said inner liner wall, said flange supporting said shroud proximate a forward joint and allowing the second portion of pressurized air to pass into said annulus.

6. The gas turbine engine set forth in claim 1 further comprising a boss extending from said cold side of said inner liner wall to said shroud, said boss having a bore communicating with an aperture in said shroud.

7. A combustion chamber having reduced emissions comprising:
an inner liner defining a combustion zone and having a wall with an outwardly facing cold side;
a shroud affixed to said inner liner, said shroud circumscribing a portion of said inner liner and being spaced apart from said cold side to form an annulus therebetween; and
a plurality of heat transfer features disposed on said cold side of said inner liner wall, wherein the combustion zone is not in fluid communication with the annulus at operating temperatures so that air in the annulus cannot enter the combustion zone.

8. The combustion chamber set forth in claim 7 wherein said heat transfer features are oriented in a pattern.

9. The combustion chamber set forth in claim 8 wherein the pattern varies.

10. The combustion chamber set forth in claim 8 wherein at least a portion of said heat transfer features are pedestals.

11. The combustion chamber set forth in claim 7 further comprising a flange extending from said cold side, said flange supporting said shroud proximate a forward joint.

12. The combustion chamber set forth in claim 7 further comprising a boss extending from said cold side of said inner liner wall to said shroud, said boss having a bore communicating with an aperture in said shroud.

13. A method of combusting fuel with reduced emissions comprising the steps of:
a. introducing a fuel inside of a liner wall without premixing in a pressurized air stream prior to ignition;

b. producing a flowing stream of combustion products by igniting the fuel and air; and

c. introducing no additional pressurized air adjacent said liner wall for reducing CO.

14. The method set forth in claim 13 further comprising the step of:

d. introducing moisture into the combustion products reducing NOx.

15. The method set forth in claim 14 wherein the moisture is introduced upstream of said liner wall.

16. The method set forth in claim 14 wherein the moisture is introduced along said liner wall.

17. A method of reducing emissions in a turbine engine having a combustion chamber defined by a wall having an inwardly facing hot side an on outwardly facing cold side, said method comprising the steps of:

a. flowing combustion products adjacent said hot side in a downstream direction;

b. flowing air adjacent said cold side in a least partially the downstream direction for reducing CO;

c. flowing moisture adjacent said hot side and in the downstream direction for reducing NOx; and

d. preventing the air adjacent said cold side from contacting said hot side at operating temperatures.

18. The method as set forth in claim 17 wherein the air flowing adjacent said cold side is constrained radially, forming a blanket.

19. The method as set forth in claim 17 wherein the moisture is introduced upstream of said combustion chamber wall.

20. The method as set forth in claim 17 wherein the moisture is introduced along said combustion chamber wall.

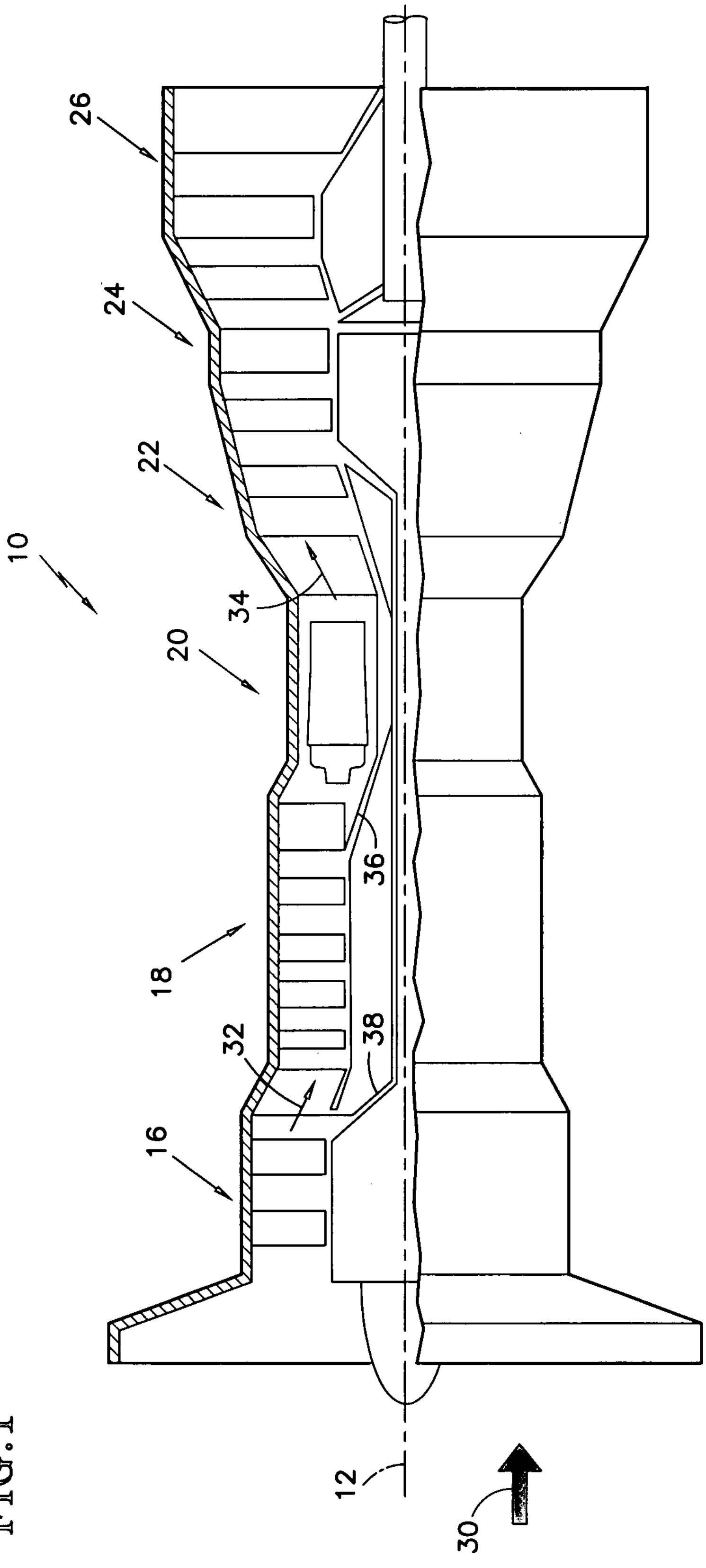

FIG. 1

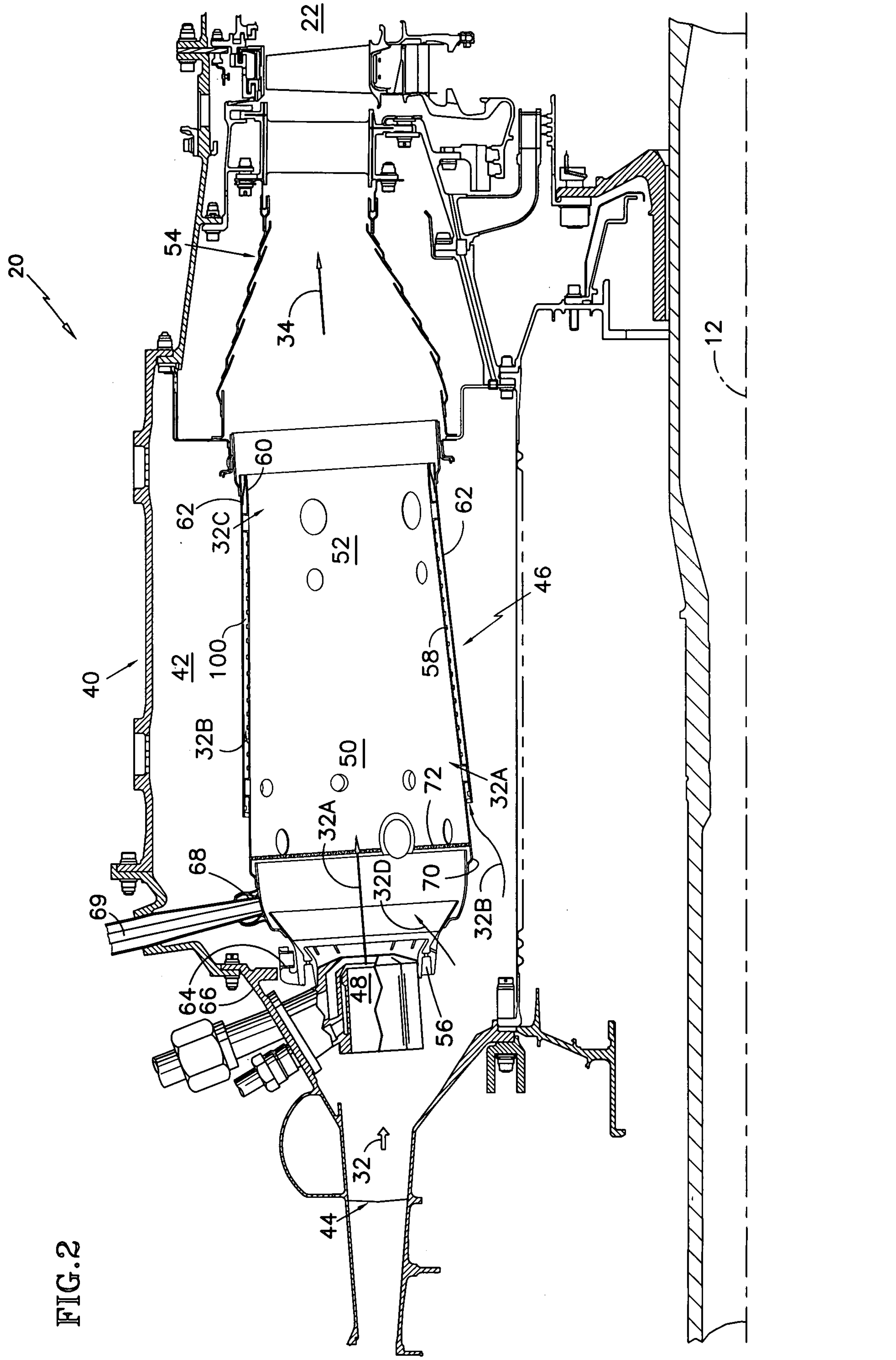
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FIG.2

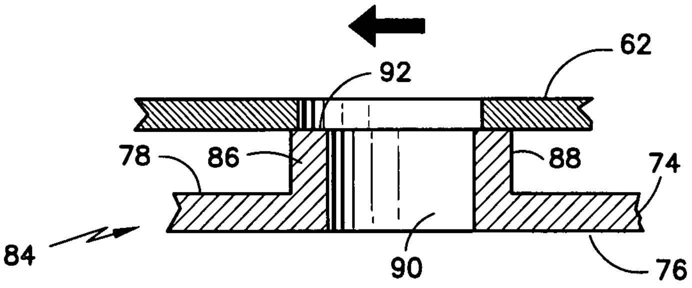
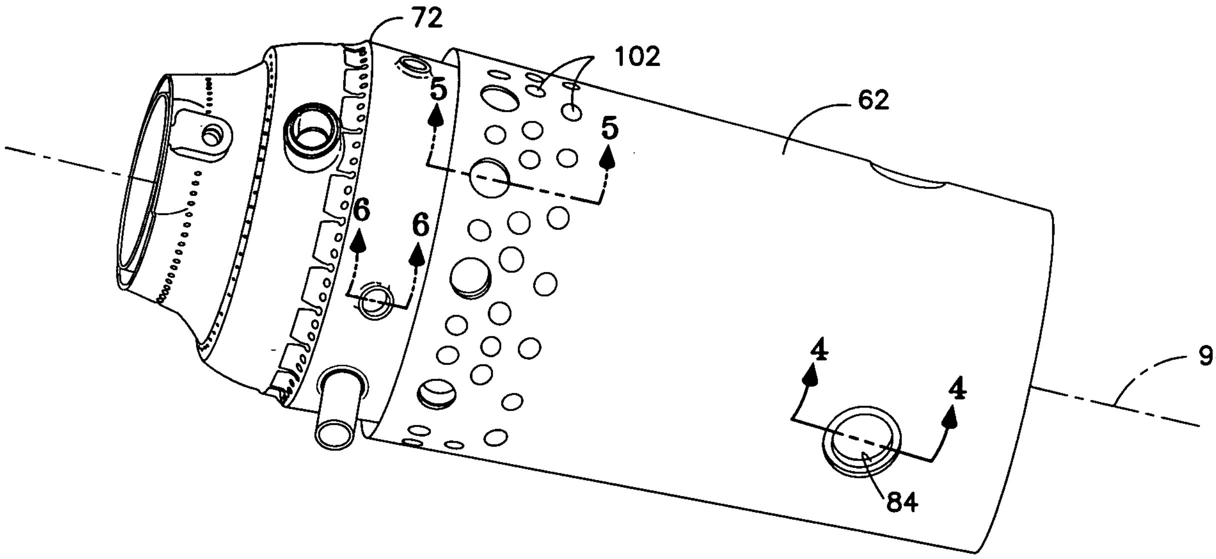


FIG.5

FIG.3



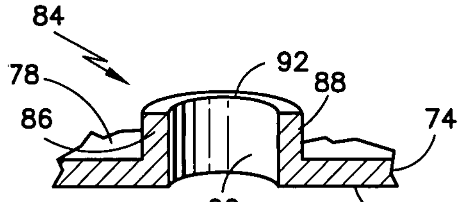


FIG.6

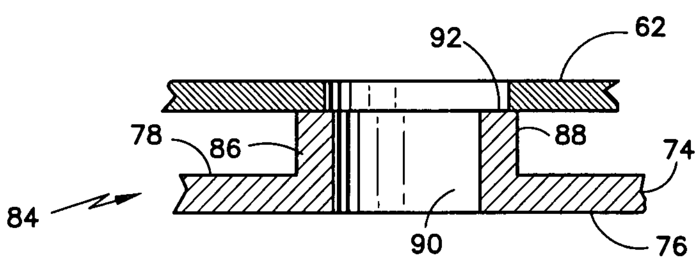
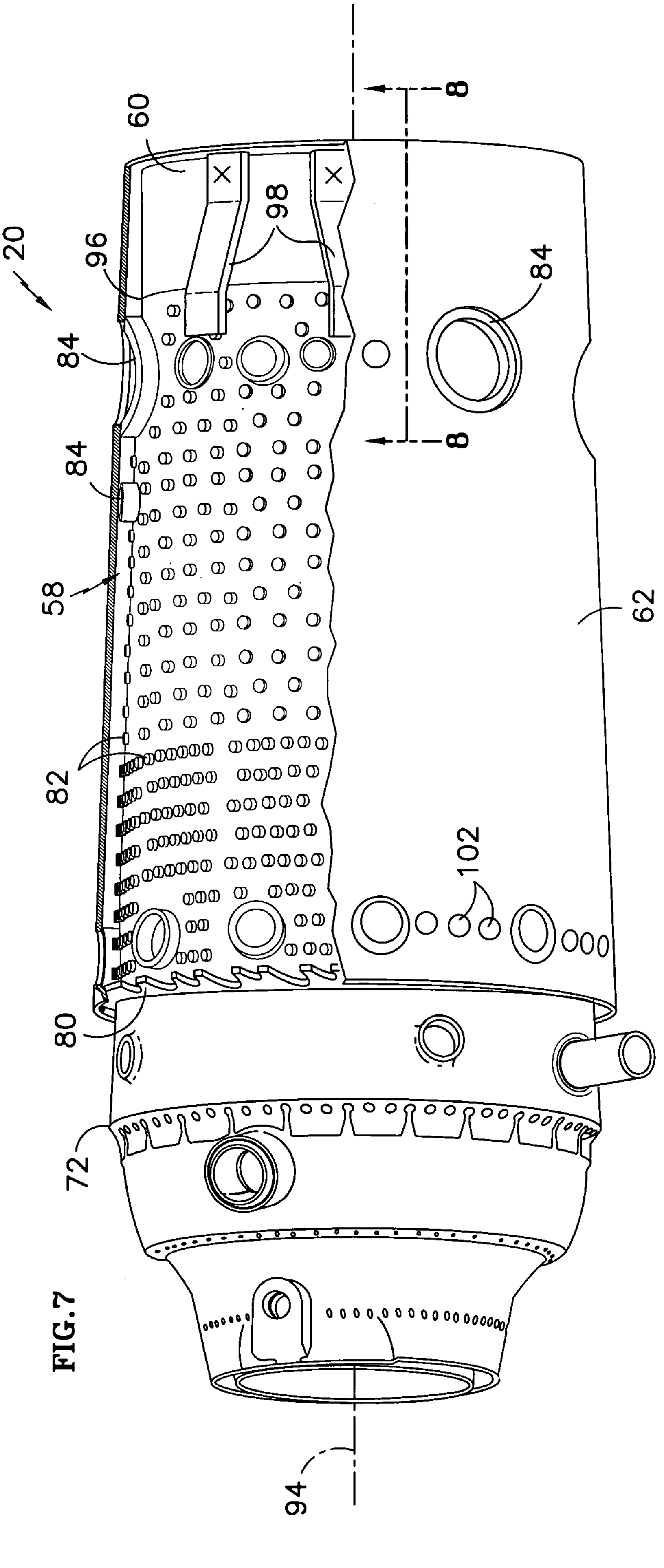


FIG.4

4/5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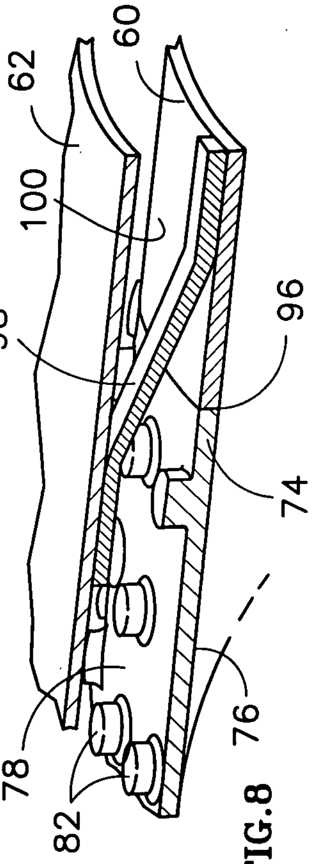
94

FIG.7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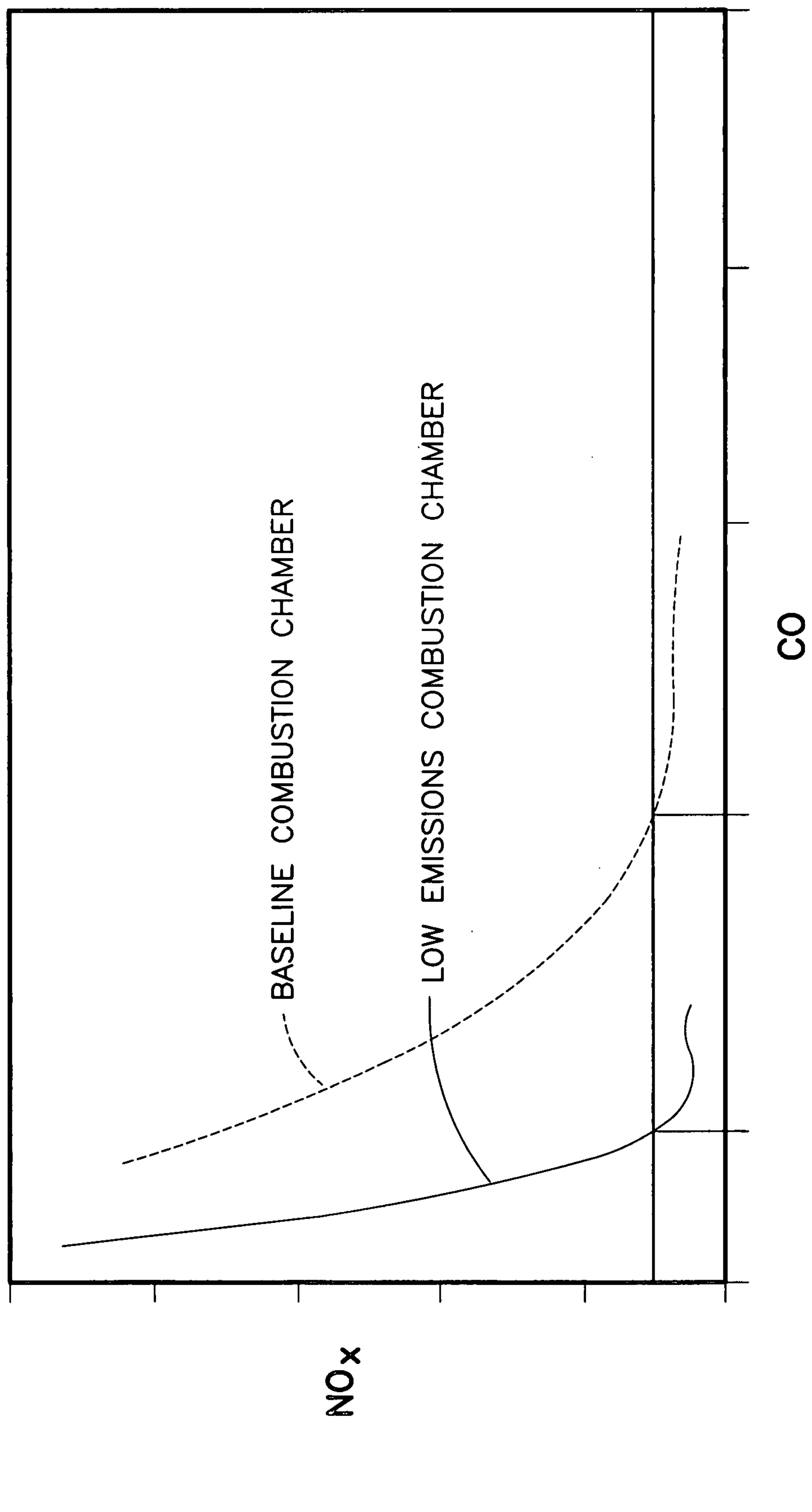
96
74
76
78
82

FIG.8

FIG.9



BASELINE COMBUSTION CHAMBER
LOW EMISSIONS COMBUSTION CHAMBER
CO
NOx

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2007/024721

A. CLASSIFICATION OF SUBJECT MATTER
INV. F23R3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F23R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2002/108375 A1 (JOHNSON ROBERT ALAN [US] ET AL) 15 August 2002 (2002-08-15) page 1, paragraph 11 - page 2, paragraph 13; figures 1-3	1,2,5,7,8,11 4,6,10,12
Y	US 6 170 266 B1 (PIDCOCK ANTHONY [GB] ET AL) 9 January 2001 (2001-01-09) column 3, line 39 - line 65 figures 2,3	4,10
Y	US 6 402 464 B1 (CHIU RONG-SHI PAUL [US] ET AL) 11 June 2002 (2002-06-11) column 7, line 65 - column 8, line 27 figures 1,2	6,12

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 September 2008	14/01/2009
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Fax: (+31–70) 340–3016	Authorized officer Gavriliu, Costin

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2007/024721

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/044857 A1 (GLEZER BORIS [US] ET AL) 3 March 2005 (2005-03-03) page 1, paragraph 14 - page 3, paragraph 24; figures 1-4	1,2,7,8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2007/024721

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search reportcovers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

see additional sheet(s)

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-12

   Cooling the liner of a gas turbine combustion chamber by means of heat transfer features disposed on the cold side of said liner, into the annuls formed by the liner and a shroud circumscribing it.

   ---

2. claims: 13-20

   A method of reducing the CO and NOx emissions by injecting moisture into the combustion products.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2007/024721

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002108375 A1	15-08-2002	US 2002152755 A1	24-10-2002
US 6170266 B1	09-01-2001	DE 69924657 D1 DE 69924657 T2 EP 0937946 A2	19-05-2005 08-09-2005 25-08-1999
US 6402464 B1	11-06-2002	NONE	
US 2005044857 A1	03-03-2005	NONE	