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• **Kraemer, Gilbert Otto**

Greenville, SC South Carolina 29615 (US)

• **Karim, Hasan UI**

Greenville, SC South Carolina 29615 (US)

• **Popovic, Predrag**

Greenville, SC South Carolina 29615 (US)

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(71) Applicant: **General Electric Company
Schenectady, New York 12345 (US)**

(72) Inventors:

- **Baruah, Abinash
560066 Bangalore, Karnataka (IN)**

(74) Representative: **Cleary, Fidelma**

GPO Europe

GE International Inc.

The Ark

201 Talgarth Road

Hammersmith

London W6 8BJ (GB)

(54) **Combustor apparatus for stoichiometric combustion**

(57) Gas turbine combustor 2 with a specific fuel and oxidizer flow arrangement 12 which provides high com-

bustion efficiency for stoichiometric diffusion combustion in gas turbine applications operating with oxygen deficient working fluids.

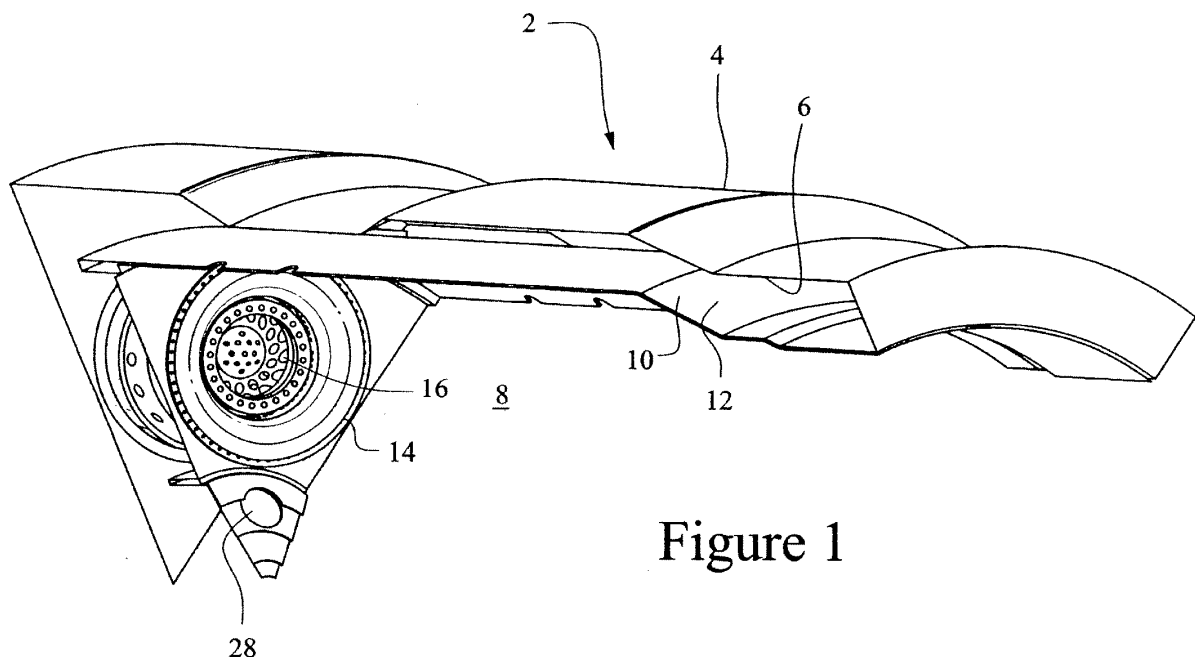


Figure 1

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Description

[0001] The present invention relates to a gas turbine combustor geometry with a specific fuel and oxidizer flow arrangement that provides high combustion efficiency for stoichiometric diffusion combustion in gas turbine applications operating with oxygen-deficient working fluids.

[0002] Gas turbine applications utilizing low oxygen working fluids are known. Examples of such applications are carbon capture, oxyfuel, and high exhaust gas recirculation, all of which require high combustion efficiency to be economically viable. However, achieving such high combustion efficiency has not been attainable to date.

[0003] A need exists for high efficiency combustion in gas turbine applications where a low oxygen working fluid is used. The present invention seeks to satisfy that need.

[0004] In one aspect, the invention provides a combustor comprising a housing having an inner surface, an interior volume, and a nozzle and a liner assembly positioned within the housing. The liner is provided with at least one liner mixing hole and at least one liner dilution hole. The liner assembly is spaced apart from the inner surface of the housing to define a path extending longitudinally along the combustor between the liner assembly and the inner surface of the housing for transporting working fluid to the interior volume through the liner mixing and dilution holes. The liner mixing and dilution holes are axially positioned in the liner assembly at specific positions as a function of the diameter of the liner.

[0005] The combustor of the invention provides a stable flame and high combustion efficiency while ensuring adequate hardware durability. Since the applications of carbon capture, oxyfuel, and high exhaust gas recirculation require near stoichiometric combustion, the combustor of the present invention provides high efficiency combustion to ensure combustion is completed before fuel and oxidizers are diluted with the gas turbine working fluid.

[0006] The combustor of the invention thus provides a cost effective solution in gas turbine applications where a low oxygen working fluid is used to achieve improved combustion efficiency as compared to that obtained using conventional combustors.

Figure 1 is a perspective partial interior view of a combustor of the invention;

Figure 2 is a side view of the liner assembly of the combustor of the invention showing the mixing and dilution holes;

Figure 3 is a perspective view of the nozzle structure employed in the combustor of the invention;

Figure 4 is a schematic cross-sectional view of the combustor;

Figure 5 is a schematic illustration of the counter-

swirl nozzle architecture;

Figure 6 is a schematic illustration of the co-swirl nozzle architecture;

Figure 7 is a partial side view of the nozzle showing an integrated igniter.

[0007] Referring to the drawings, Figure 1 shows a perspective interior view of the combustor 2 of the invention having a housing 4 with an inner surface 6 and an interior volume 8. A liner assembly 10 is provided within the housing 4 and is spaced apart from the inner surface 6 of the housing to define a path 12 extending longitudinally along the length of the combustor 2 between the liner assembly 10 and the inner surface 6, along which gas turbine (GT) diluent rich working fluid flows.

[0008] Figures 1 and 3 also show a nozzle 14 provided at one end of the combustor 2. The nozzle 14 is in flow communication with the interior volume 8 of the combustor 2. The nozzle 14 is provided with a series of concentric apertures defining fuel holes 16.

[0009] The nozzle structure employed in the present invention is described in detail in commonly assigned US 2009/0223227, filed March 5, 2008 (herein incorporated by reference).

[0010] Figure 2 shows the liner assembly 10 provided with liner mixing holes 18, 20, liner dilution holes 40, 42 and liner cooling holes 44, 46, 48 at different axial locations along the liner 10. According to the invention, the liner mixing holes 18, 20 are sized and positioned in the liner assembly 10 at axial locations to provide good mixing of fuel components and complete combustion. In one embodiment, for example, the liner mixing holes 18, 20 are sized to provide about 10% of the GT flow, i.e., the flow available for the combustor from the compressor. Jets injected from the fuel nozzle through the liner mixing holes restrict the expansion of the oxidizer stream which promotes shear mixing between fuel and oxidizer. The location of the liner mixing holes may be optimized to avoid flame quenching. This is discussed below in relation to Figure 4.

[0011] Figure 4 shows the liner mixing holes 18, 20 situated at an axial distance L from the nozzle 14 which is typically $0.65-1.05D$, where D is the internal diameter of the liner 10. The liner mixing holes generate a jet penetration into the interior volume 8 of the liner of $1.05-1.4D_1$, where D_1 is the diameter of the mixing hole.

[0012] The cooling holes 44, 46, 48 are positioned at different axial locations and are designed to accommodate, for example, about 30-32% of the GT working fluid at compressor discharge (i.e., the exit station of the compressor and starting station of the combustor). The size and number of cooling holes at any particular location is based on the desired effective heat transfer at that location.

[0013] Crown hole 28 accommodates about 6-9% of the GT working fluid at compressor discharge. The crown

hole 28 creates a recirculation bubble 50 of length L2 of 0.65-1.05D where D is the internal diameter of the liner 10. This provides for higher combustion efficiency.

[0014] The dilution holes 40, 42 are situated at an axial distance L3 of 1.3-1.7 D, where D is the internal diameter of the liner. The dilution holes create a jet penetration of L4 which is 1.4-1.6 times D2, where D2 is the diameter of the dilution hole. Strong shear mixing occurs between the oxidizer and fuel resulting in rapid reaction with a short residence time promoting a larger reaction zone. In addition, the mixing with the GT working fluid helps in controlling the peak flame temperature while keeping the flame away from the nozzle. The dilution holes accommodate 8-11 % of the total combustor flow.

[0015] The center passage 24 of the nozzle is generally used for oxidizer flow, such as air, oxygen, diluted oxygen or fuel. The outer passages 22, 26 are intended for gas turbine (GT) working fluid (typically a diluent rich fluid). The passages 22, 24, 26 are typically inclined such that they produce counter-rotating flow between the oxidizer and GT working fluid. This is illustrated in Figure 5 which illustrates schematically the gases exiting the nozzle into the interior volume 8 in a counter-swirling manner. Figure 6 illustrates an example of co-swirling where the gases exit the nozzle into the interior volume 8 in a co-swirling manner.

[0016] The center passage 24 of the nozzle 14 typically contains angled fuel injection holes with an angle range from 40-60 degrees to produce high swirling flow. The center annular passage 24 of the nozzle is intended for gaseous fuel flow and is typically inclined with a cone angle of 20-26 degrees and a swirl angle of 5-16 degrees to the nozzle axis to induce counter-clockwise swirling (see Figure 5). The outer annular passage 26 is generally intended for diluent flow and is inclined with a cone angle of 30-36 degrees and swirl angle of 5-16 degrees to the nozzle axis to induce clockwise rotation. In such a flow arrangement, the strong shear mixing between the oxidizer and fuel results in the rapid reaction with a short residence time promoting larger reaction zone than in prior arrangements.

[0017] The center passage 24 of the nozzle is designed to flow a blended fluid containing 20-80% of the oxidizer and 80-20% of the GT working fluid at compressor discharge. The blending is optimized to control the reaction rates, and flame temperature to lower the dissociation loss from the reaction zone. The outer passage 26 is designed to flow 25-30% of the total combustor flow. This flow arrangement acts to delay the combustion reaction downstream of the nozzle and thereby avoid potential risk of hardware damage.

[0018] Figure 7 shows an integrated igniter 30 on the nozzle 14 for igniting the combustible charge. The igniter is typically located at an angle of 25-30 degrees to the nozzle longitudinal axis. A pilot nozzle 52 may alternatively be provided for startup application. The pilot nozzle, if present, is usually located in the middle of the fuel nozzle that passes liquid fuel.

[0019] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

10 Claims

1. A combustor (2) comprising a housing (4) having an inner surface (6), a nozzle (14) and a liner assembly (10) positioned within said housing (4), said liner having an interior volume and being spaced apart from the inner surface of the housing (4) to define a path (12) extending longitudinally along the combustor for transporting working fluid to said interior volume, said liner being provided with mixing holes (18,20) and dilution holes (40,42) positioned longitudinally along said liner as a function of the internal diameter of the liner.
2. A combustor according to claim 1, wherein liner mixing holes are positioned at an axial distance from the nozzle of 0.65-1.05D, where D is the internal diameter of the liner.
3. A combustor according to claim 1 or claim 2, wherein the liner mixing holes generate a jet penetration into the interior volume of the liner 1.05-1.4 D1, where D1 is the diameter of the mixing hole.
4. A combustor according to any preceding claim, wherein the dilution holes are positioned at an axial distance from the nozzle of 1.3-1.7 D, where D is the internal diameter of the liner.
5. A combustor according to any preceding claim, wherein the dilution holes create a jet penetration into the interior volume of the liner of 1.4-1.6 D2, where D2 is the diameter of the dilution hole.
6. A combustor according to any preceding claim, wherein crown holes are provided which accommodate about 6-9% of the working fluid.
7. A combustor according to any preceding claim, wherein the crown hole creates a recirculation bubble of length of 0.65-1.05 D, where D is the internal diameter of the liner.
8. A combustor according to any preceding claim, wherein the dilution holes accommodate 8-11 % of the total combustor flow.
9. A combustor according to any preceding claim, wherein cooling holes are provided which accommo-

date 30-32% of the working fluid at compressor discharge.

10. A combustor according to any preceding claim, wherein the outer passage flows 25-30% of the working fluid at compressor discharge. 5
11. A combustor according to any preceding claim, wherein an integrated igniter is provided for igniting the working fluid. 10
12. A combustor according to any preceding claim, in which the nozzle passages are inclined such that they produce counter-rotating flow between the oxidizer and working fluid. 15
13. A combustor according to any preceding claim, in which the nozzle passages are inclined such that they produce co-rotating flow between the oxidizer and working fluid. 20
14. A gas turbine including a combustor according to any preceding claim. 25

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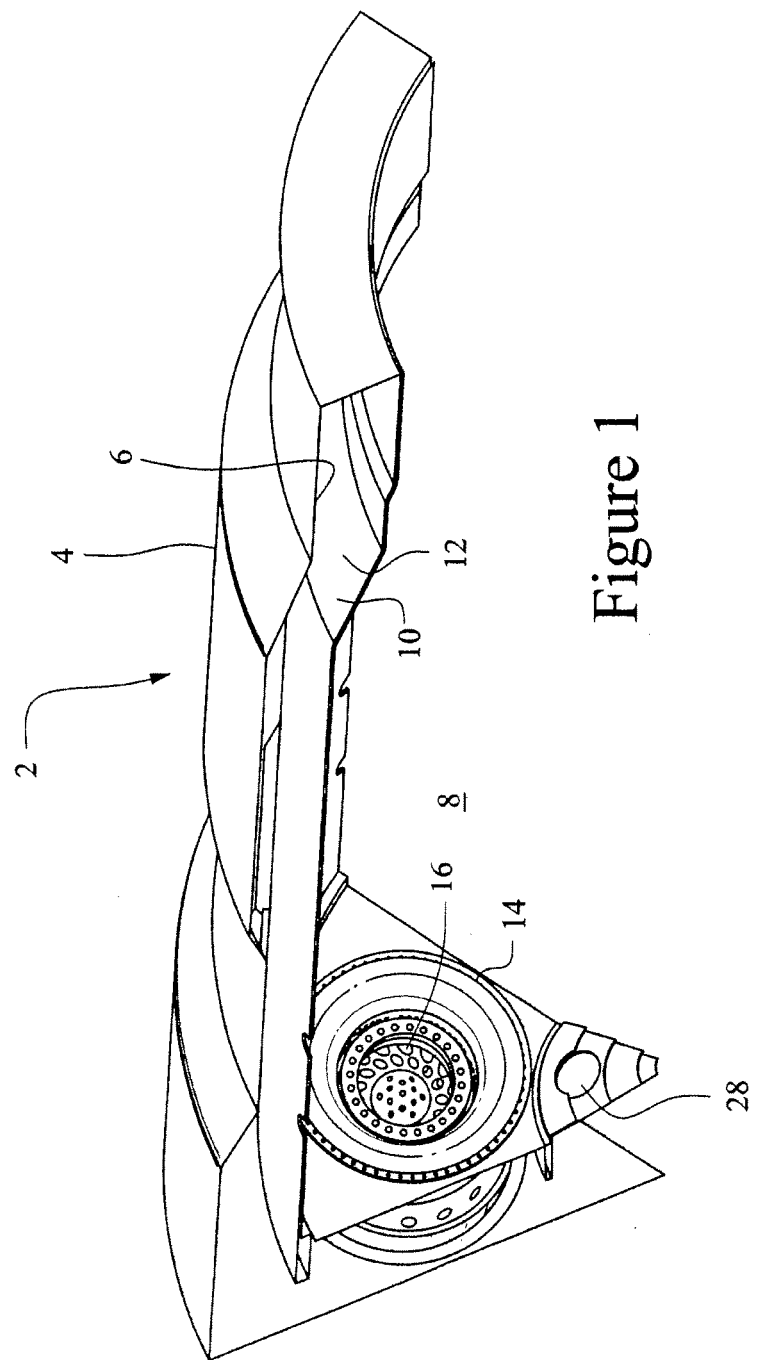


Figure 1

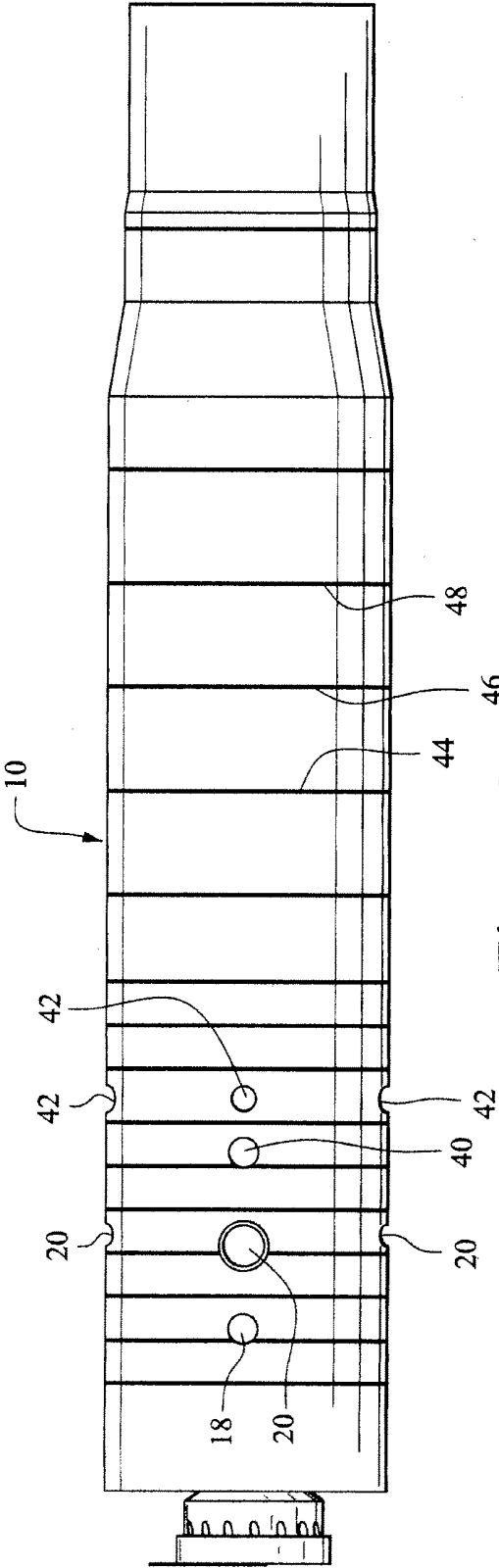


Figure 2

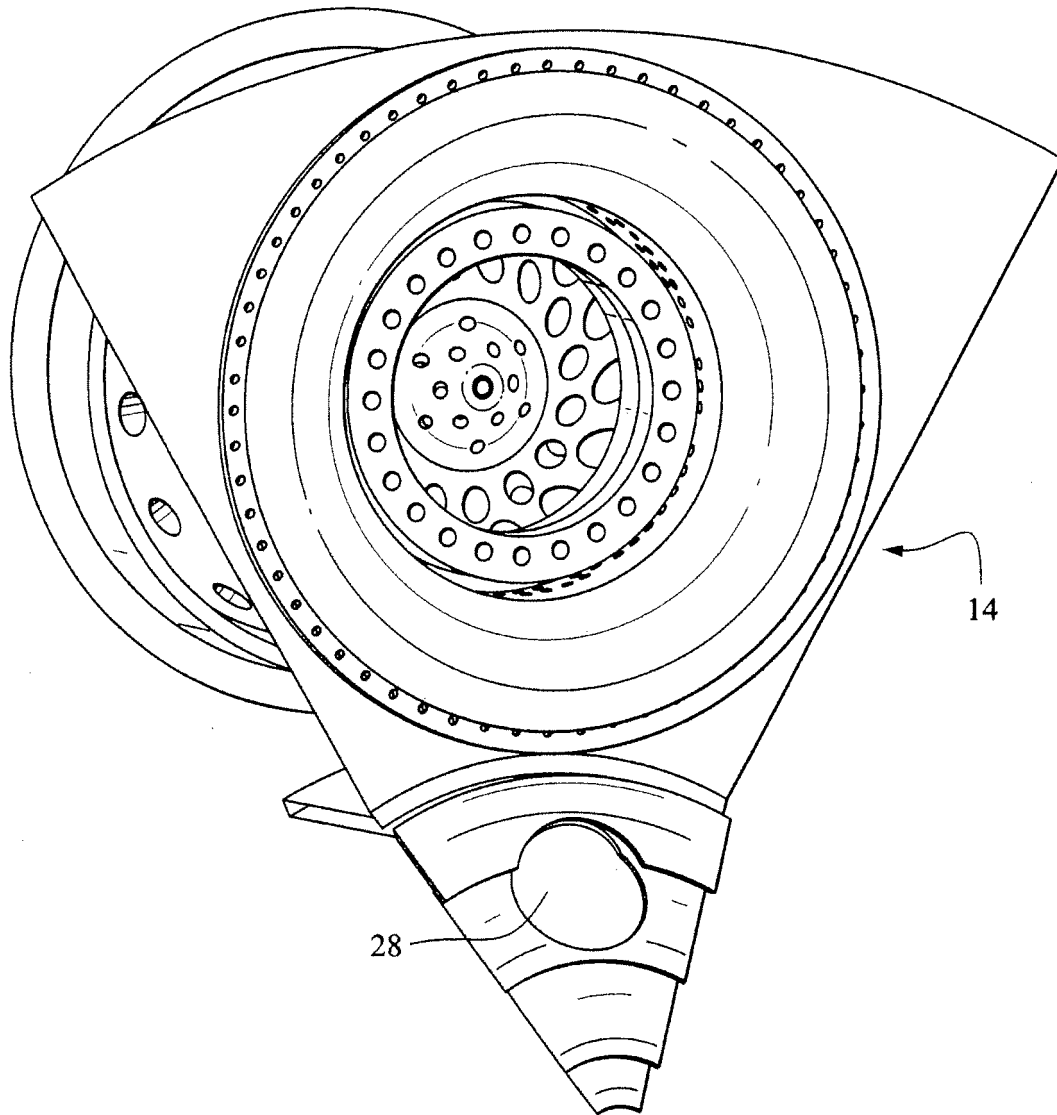


Figure 3

Residence Time calculation

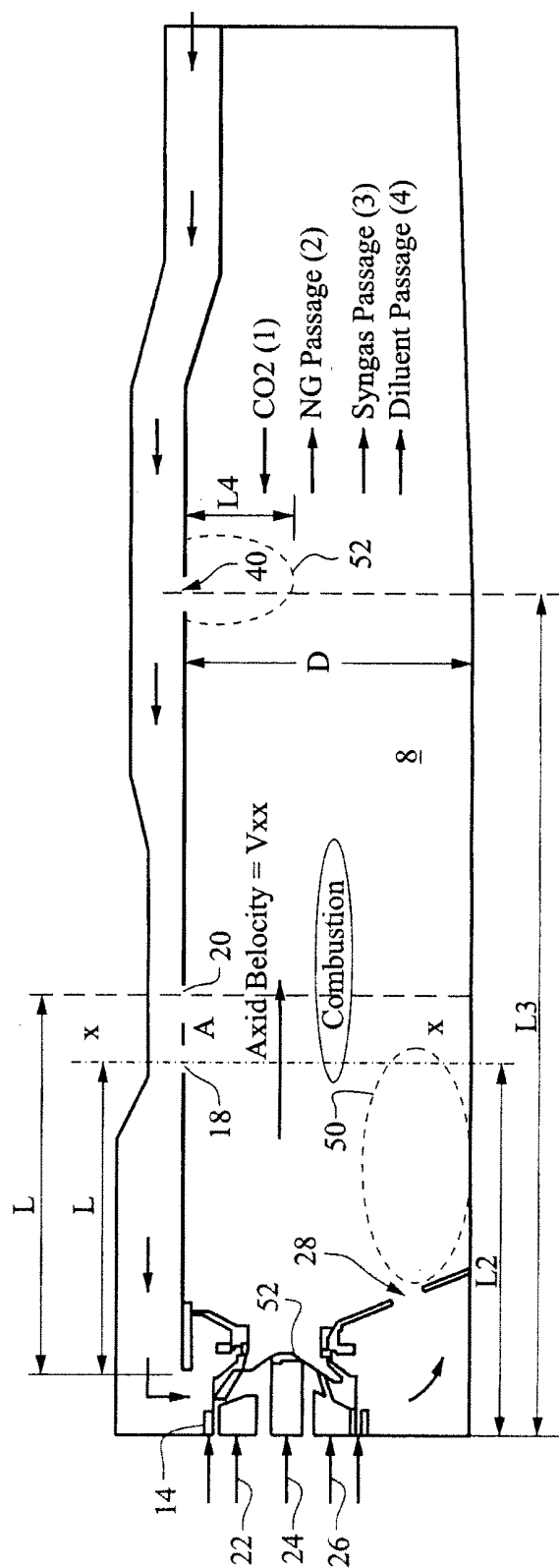


Figure 4

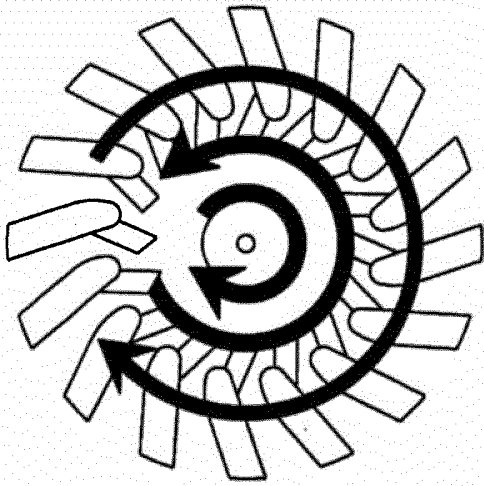


Figure 5

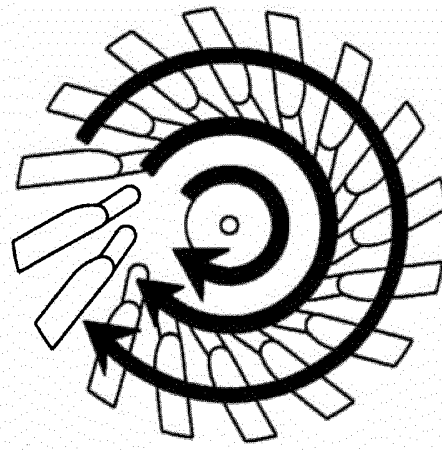


Figure 6

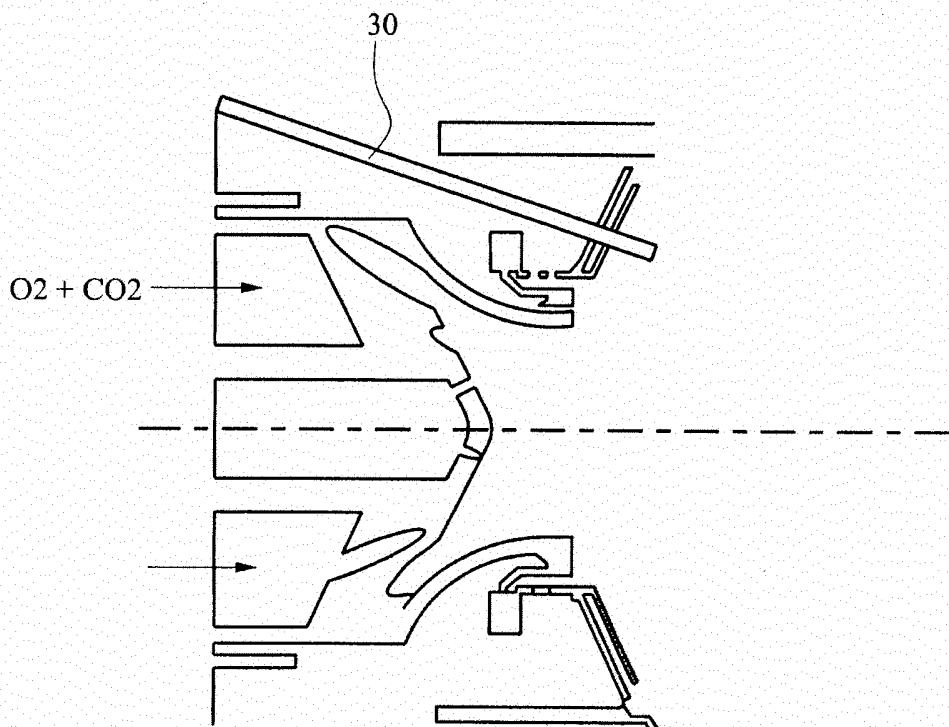


Figure 7

REFERENCES CITED IN THE DESCRIPTION

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