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(54) **COMBUSTOR UNIT FOR A GAS TURBINE ASSEMBLY, GAS TURBINE ASSEMBLY AND METHOD FOR CONTROLLING FUEL INJECTION IN A COMBUSTOR UNIT FOR A GAS TURBINE ASSEMBLY**

(57) A combustor unit (10) for a gas turbine assembly (1) comprises a premix combustor (15) and a reheat combustor (16), which are arranged in series along the gas flow direction (M); the reheat combustor (16) comprises: a housing (20) extending substantially along a longitudinal axis (B) and defining a reheat combustion chamber (23), a plurality of injection units (27) distributed around the reheat combustion chamber (23) and fed with air and fuel; at least one first injection unit (27a) of the plurality of injection units (27) being configured to inject fuel and air differently with respect to the others injection units (27b, 27c, 27d, 27e).

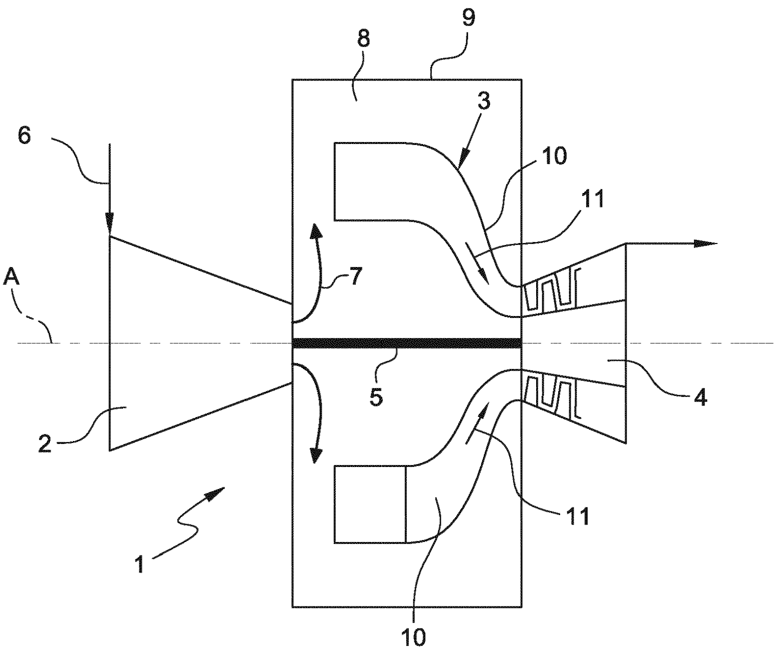

FIG. 1

EP 4 019 840 A1

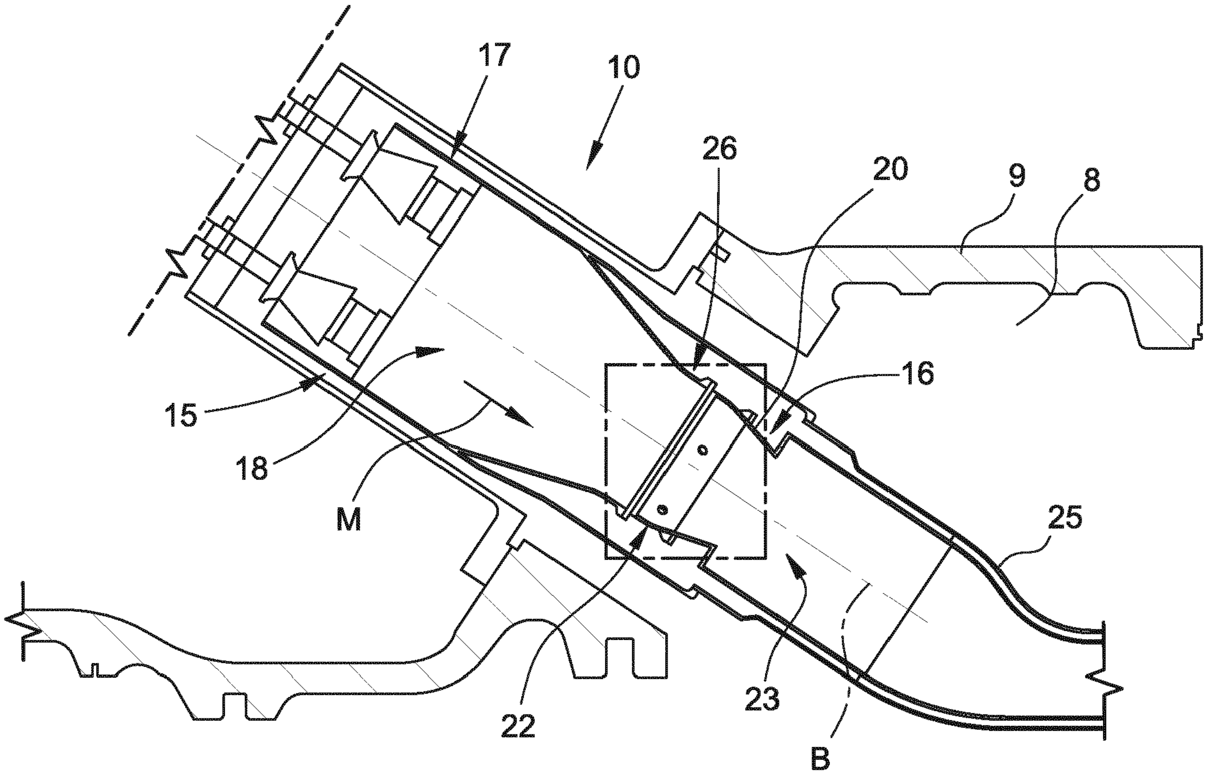

FIG. 2a

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a combustor unit for a gas turbine assembly and to a gas turbine assembly, in particular of a power plant.

[0002] The invention further relates to a method for controlling fuel injection in a combustor unit.

DESCRIPTION OF PRIOR ART

[0003] As is known, a gas turbine assembly for power plants comprises a compressor, a combustor unit and a turbine.

[0004] In particular, the compressor comprises an inlet, supplied with air, and a plurality of blades compressing the passing air. The compressed air leaving the compressor flows into a plenum, i.e. a closed volume, and from there into the combustor unit, where the compressed air is mixed with at least one fuel and combusted. The resulting hot gas leaves the combustor unit and is expanded in the turbine, producing mechanical work.

[0005] In order to achieve a high efficiency, a high turbine inlet temperature is required.

[0006] However, due to this high temperature, high NOx emissions are generated.

[0007] In order to reduce these emissions and to increase operational flexibility, gas turbine assemblies have been developed which comprise a combustor unit performing a sequential combustion cycle.

[0008] In general, a sequential combustor unit comprises two combustors in series, wherein each combustor is provided with a respective burner and combustion chamber. Following the main gas flow direction, the upstream combustor is called "premix" combustor and is fed by the compressed air. The downstream combustor is called "sequential" or "reheat" combustor and is fed by the hot gas leaving the first combustion chamber.

[0009] According to a first known configuration, the two combustors are physically separated by a high pressure turbine. Following the main gas flow, this first configuration includes the compressor, the premix combustor, the high-pressure turbine, the reheat combustor and a low-pressure turbine.

[0010] According to a second known configuration, the premix and the reheat combustor are arranged directly one downstream the other inside a common casing, in particular a can-shaped casing, and no high-pressure turbine is used. According to this kind of sequential gas turbines, a plurality of can combustors are provided, which are distributed around the turbine axis.

[0011] Each reheat combustor is preferably provided with a reheat burner and a reheat combustion chamber into which the hot flow coming from the premix is discharged. A transition duct is arranged downstream the reheat combustion chamber and guides the hot gas leaving the reheat combustor toward the turbine.

[0012] The reheat burner may include a plurality of identical injection units, which are circumferentially arranged about the reheat combustion chamber and are designed to uniformly inject fuel into the reheat combustion chamber.

[0013] The reheat burner flames, in certain operating conditions, generate self-excited thermoacoustic pulsations, which may exceed acceptable pulsation limits and undesirably restrict the gas turbine operational range.

[0014] For this reason, usually, combustor assemblies are provided with damping devices in order to damp these pressure oscillations. However, damping devices are not always effective and require space, not always available in all combustor assemblies.

SUMMARY OF THE INVENTION

[0015] Therefore it is primary object of the present invention to provide a combustor unit wherein flame pulsations are reduced in a cost effective way and, at the same time, without affecting NOx emissions.

[0016] This object is attained, according to the present invention, by a combustor unit for a gas turbine assembly comprising a premix combustor and a reheat combustor, which are arranged in series along the gas flow direction; the reheat combustor comprising:

- a housing extending substantially along a longitudinal axis and defining a reheat combustion chamber,
- a plurality of injection units distributed around the reheat combustion chamber and fed with air and fuel;
- at least one first injection unit of the plurality of injection units being configured to inject fuel and air differently with respect to the others injection units.

By designing the injection units according to a non-uniform distribution pattern, when operational conditions occur that are prone to undesired thermoacoustic pulsations, the flame behavior is controlled and instability prevented or reduced. The non-uniformity of the injection units, in fact, creates an uneven distribution of the characterizing features of the flames (local delay time, flame front etc.). In this way thermoacoustic pulsations not only do not increase, but are reduced by disruptive interference.

According to a variant, all the injection units of the plurality of injection units are configured to inject fuel and air differently from each other.

According to a variant of the present invention, the at least one first injection unit of the plurality of injection units is configured to inject fuel and air according to a different equivalence ratio and/or to a different mixing between air and fuel and/or to a different penetration into the reheat combustion chamber with respect to the other injection units. According to a further variant of the present invention, the geometry of the at least one first injection unit of the plurality of injection units is different from the geometry of the other injection units of the plurality of injection units.

According to a variant of the present invention, the amount of air and/or fuel fed to the at least one first injection unit of the plurality of injection units is different from the amount of air and/or fuel fed to the other injection units of the plurality of injection units.

According to a variant of the present invention, each injection unit of the plurality of injection units engages a respective hole of the housing.

According to a variant of the present invention, each injection unit of the plurality of injection units comprises a fuel supply line and at least one fuel nozzle in fluidic communication with the fuel supply line; an air supply line and at least one air nozzle in fluidic communication with the air supply line; and a conveying tube extending along an extension axis and provided with an outlet flowing into the reheat combustion chamber; in the conveying tube air and fuel coming from the at least one fuel nozzle and air nozzle are mixed.

According to a further variant of the present invention, the inlet of the conveying tube coincides with the air nozzle.

According to a variant of the present invention, the at least one first injection unit has a conveying tube having a first tube length different from the tube lengths of the conveying tubes of the other injection units.

Preferably, according to an embodiment of the present invention, the at least one first fuel nozzles of the at least one first injection unit has a first diameter different from the diameters of the fuel nozzles of the other injection units.

According to another embodiment of the present invention, the at least one first injection unit has a first conveying tube having a first tube width different from the tube widths of the conveying tubes of the other injection units.

According to another embodiment of the present invention, the at least one first injection unit has a first air nozzle having a passage section different from the passage sections of the air nozzles of the other injection units.

According to another embodiment of the present invention, the first injection unit comprises a metering plate provided with a hole and coupled to the first air nozzle to adjust the passage section of the first air nozzle.

According to another embodiment of the present invention, the at least first injection unit has a first conveying tube extending along an extension axis which is inclined differently from the extension axes of the conveying tubes of the other injection units.

[0017] It is also another object of the present invention to provide a gas turbine assembly wherein flame pulsations are reduced in a cost effective way and, at the same time, without affecting NOx emissions.

According to these objects the present invention relates to a gas turbine assembly as claimed in claim 15.

BRIEF DESCRIPTION OF DRAWINGS

[0018] For a better comprehension of the present invention and its advantages, an exemplary embodiment of the invention is described below in conjunction with the accompanying drawings, in which:

- figure 1 is a schematic view, with parts removed for clarity, of a gas turbine assembly provided with a combustor unit according to the present invention;
- figure 2a is a schematic lateral section view, with parts removed for clarity, of a combustor unit according to the invention;
- figure 2b is an enlarged view of a detail of figure 2a;
- figures 3a-3c are schematic enlarged section views of details of the combustor unit of figure 2;
- figures 4a-4c are schematic enlarged section views of details of the combustor unit of figure 2 according to a first variant of the present invention;
- figures 5a-5c are schematic enlarged section views of details of the combustor unit of figure 2 according to a second variant of the present invention;
- figures 6a-6c are schematic enlarged section views of details of the combustor unit of figure 2 according to a third variant of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0019] Figure 1 is a schematic view of a gas turbine assembly 1 for power plants according to the present invention.

[0020] Gas turbine assembly 1 comprises a compressor 2, a combustor assembly 3 and a turbine 4. Compressor 2 and turbine 4 have a common axis A and form respective sections of a rotor 5 rotatable about axis A.

[0021] As is known, ambient air 6 enters compressor 2 and is compressed. Compressed air 7 leaves compressor 2 and enters a plenum 8, i.e. a volume defined by an outer casing 9. From plenum 8, compressed air 7 enters combustor assembly 3 that comprises a plurality of combustor units 10 annularly arranged around axis A. Combustor units 10 are often defined "can combustors". In combustor units 10 at least a fuel is injected, and the air/fuel mixture is ignited, producing hot gas 11 that is conveyed to turbine 4.

[0022] As is better shown in figure 2a, each combustor unit 10 is housed in a respective portal hole of the outer casing 9 and has an axis B. Combustor unit 10 comprises, in series along gas flow M, a first or premix combustor 15, a second or reheat combustor 16 and a transition duct 19, which guides the hot gas leaving the reheat combustor 16 toward the turbine 4.

[0023] In particular, premix combustor 15 comprises a premix burner 17 and a first combustion chamber 18.

[0024] Reheat combustor 16 comprises a housing 20 defining a combustion chamber 23 and a reheat burner 22.

[0025] Preferably, the housing 20 is a double wall housing wherein a cooling interspace 24 (better visible in figures 3a-3c, 4a-4c, 5a-5c, 6a-6c) is formed. The cooling interspace 24 is fed with air coming from the plenum 8.

[0026] The housing 20 is arranged inside a casing 25, which substantially surrounds the housing 20 in order to create an air chamber 26, which is fed with the air coming from the plenum 8.

[0027] With reference to figure 2b, reheat burner 22 comprises a plurality of injection units collectively referenced 27, and individually referenced 27a, 27b, 27c, 27d, etc....

[0028] The plurality of injection units 27 is arranged around the reheat combustion chamber 23 and is fed with air and fuel. Preferably,, the plurality of injection units 27 is arranged circumferentially around the reheat combustion chamber 23.

[0029] Each injection unit 27a, 27b, 27c, 27d, etc. engages a respective through hole 28 made in the housing 20.

[0030] With reference to figures 3a-3c, each injection unit 27a, 27b, 27c, 27d comprises a fuel supply line 30 and at least one fuel nozzle 31 in fluidic communication with the fuel supply line 30, an air supply line 29 and at least one air nozzle 32 in fluidic communication with the air supply line 29 and a conveying tube 33, wherein air and fuel coming from the at least one fuel nozzle 31 and air nozzle 32 are mixed.

[0031] The conveying tube 33 extends along an axis C. In the non-limitative example here disclosed and illustrated, the conveying tube 33 extends from an inlet coinciding with the air nozzle 32 to an outlet 35 flowing into the reheat combustion chamber 23.

[0032] Preferably, the conveying tube 33 is cylindrical and is at least partially housed in the hole 28 of the housing 20

[0033] The air supply line 29 comprises the air chamber 26, which surrounds the housing 20 and supplies all the air nozzles 32.

[0034] The fuel supply line 30 comprises a fuel conduit 37 (schematically represented) and a fuel collector 38, preferably surrounding the inlet portion of the conveying tube 33. The fuel supplied to the fuel supply line 30 can be the same fuel supplied to the first combustor 15 or a different fuel.

[0035] In the non-limitative example here disclosed and illustrated, each injection unit 27a, 27b, 27c, 27d, 27e comprises a plurality of fuel nozzles 31, which are arranged along a substantially circumferential path extending on a plane orthogonal to axis C.

[0036] At least one injection unit 27a of the plurality of injection units 27 is configured to inject fuel and air differently from the other injection units of the plurality of injection units 27.

[0037] With the expression "differently" it is intended that the geometry or the supply control of air and/or fuel is different from the geometry or the supply control of the other injection units 27b, 27c, 27d, 27e of the plurality of injection units 27.

[0038] Preferably, the injection unit 27a is configured to inject fuel and air according to a different equivalence ratio and/or to a different mixing between air and fuel and/or to a different penetration into the reheat combustion chamber 23 with respect to the others injection units 27b, 27c, 27d, 27e of the plurality of injection units 27.

[0039] With the expression "equivalence ratio" is intended the ratio ϕ, which is defined according to the following formula:

$$\phi = \frac{QF/QA}{(QF/QA)_{STOICH}}$$

as the ratio of the fuel-to-air ratio to the stoichiometric fuel-to-air ratio.

[0040] The advantage of using equivalence ratio over fuel-air ratio is that it takes into account (and is therefore independent of) both mass and molar values for the fuel and air.

[0041] With the expression "mixing between air and fuel" is intended the way of mixing the fuel and the air supplied to the injection unit (e.g. presence of vortex generators/deflectors and other means for controlling the mixing between fuel and air).

[0042] With the expression "penetration into the reheat combustion chamber" is intended the jet characteristic of the mixed air/fuel flow, which is injected into the reheat combustion chamber 23. In particular, the jet characteristic of the mixed air/fuel flow can depend on the jet momentum, the jet diameter, the jet angle, and the position at which the mixed air/fuel flow coming from the injection unit is injected in the reheat combustion chamber 23.

[0043] In this way, in the reheat combustion chamber 23 at least one non-uniformity is introduced. This leads to an uneven distribution of the flow field and of the hot gas, fuel, air mixing field at the reaction zone (flame) of the reheat combustor 16. The acoustic dynamics are therefore damped and the dangerous increasing of some acoustic oscillations is avoided.

[0044] In figures 3a-3c it is represented a first embodiment of the present invention wherein at least the injection unit 27a has a conveying tube 33a having a tube length La different from the tube lengths Lb, Lc, Ld, Le of the conveying tubes 33b, 33c, 33d, 33e of the other injection units 27b, 27c, 27d, 27e. The tube length is measured along the axis C.

[0045] Preferably, the tube length La is greater than the tube lengths Lb, Lc, Ld, Le of the conveying tubes 33b, 33c, 33d, 33e of the other injection units 27b, 27c, 27d, 27e.

[0046] More preferably, the tube length La is greater than the depth of the housing 20.

[0047] According to a variant not shown, the tube lengths La, Lb, Lc, Ld, Le are different from each other in order to change the penetration depth of each injection unit 27.

[0048] In figures 4a-4c it is represented a second embodiment of the present invention, wherein at least the injection unit 27a has fuel nozzles 31a having a diameter Da different from the diameter Db, Dc, Dd, De of the fuel nozzles 31b, 31c, 31d, 31e of the other injection units 27b, 27c, 27d, 27e.

[0049] Preferably, fuel nozzles 31a have a diameter Da greater than the diameters Db, Dc, Dd, De of the fuel nozzles 31b, 31c, 31d of the other injection units 27b, 27c, 27d, 27e.

[0050] According to a variant not shown, the diameters Da, Db, Dc, Dd, De of the fuel nozzles 31a, 31b, 31c, 31d, 31e are different from each other in order to change the equivalence ratio and the mixing between air and fuel of each injection unit 27

[0051] In figures 5a-5c it is represented a third embodiment of the present invention, wherein at least the injection unit 27a has a conveying tube 33a having a tube width Wa different from the tube widths Wb, Wc, Wd, We of the conveying tubes 33b, 33c, 33d, 33e of the other injection units 27b, 27c, 27d, 27e. The tube width is measured along a direction orthogonal to axis C.

[0052] Preferably, the tube width Wa is smaller than the tube widths Wb, Wc, Wd, We of the conveying tubes 33b, 33c, 33d, 33e of the other injection units 27b, 27c, 27d, 27e.

[0053] According to a variant not shown, the tube widths Wa, Wb, Wc, Wd, We are different from each other in order to change the equivalence ratio and the mixing between air and fuel of each injection unit 27 and the penetration into the reheat combustion chamber 23.

[0054] In figures 6a-6c it is represented a fourth embodiment of the present invention, wherein at least the injection unit 27a has an air nozzle 32a having a passage section Aa different from the passage sections Ab, Ac, Ad, Ae of the air nozzles 32b, 32c, 32d, 32e of the other injection units 27b, 27c, 27d, 27e.

[0055] Preferably, air nozzle 32a has a passage section Aa smaller from the passage sections Ab, Ac, Ad, Ae of the air nozzles 32b, 32c, 32d, 32e of the other injection units 27b, 27c, 27d, 27e.

[0056] More preferably, air nozzle 32a is coupled to a metering plate 39 having a hole 40 whose passage section is the desired one Aa.

[0057] According to a variant not shown, the passage sections Aa, Ab, Ac, Ad, Ae of the air nozzles 32a, 32b, 32c, 32d, 32e of the injection units 27a, 27b, 27c, 27d, 27e are different from each other in order to change the equivalence ratio and the mixing between air and fuel of each injection unit 27

[0058] In the examples here disclosed and illustrated all the conveying tubes 33a, 33b, 33c, 33d, 33e extend along an axis B which is substantially arranged radially with respect to the axis B of the combustor unit 10.

[0059] According to a variant not shown, at least one of the injection units 27a, 27b, 27c, 27d, 27e is provided with a conveying tube 33a, 33b, 33c, 33d, 33e extending along an axis which is not radially arranged.

[0060] According to a further variant all the conveying tubes 33a, 33b, 33c, 33d, 33e extend along respective axis which are not radially arranged and are inclined differently from each other.

[0061] According to a variant not shown, at least one of the injection units 27a is provided with fuel nozzles 31a having a shape and/or a position different from the shapes and/or the positions of the other fuel nozzles 31b, 31c, 31d, 31e.

[0062] According to a further variant not shown, the shapes and/or the positions of fuel nozzles 31a, 31b, 31c, 31d, 31e are different from each other in order to change the equivalence ratio and the mixing between air and fuel of each injection unit 27.

[0063] According to a variant not shown the supply line 30 can be adjusted in order to supply a different fuel flow rate to at least one injection unit of the plurality of injection units 27. For example, the passage section of the fuel conduit 37 of at least one injection unit 27a can be different from the passage section of the fuel conduits 37 of at least one injection units 37b, 37c, 37d, 37e.

[0064] According to a further variant not shown, at least one injection unit of the plurality of injection units 27 is provided with a combination of the different features above described for each embodiment.

[0065] Other variants may be considered and focused on changing further geometrical parameters of the injection units able to modify the equivalence ratio and/or the mixing between air and fuel and/or the penetration into the reheat combustion chamber 23.

[0066] In this way a different behavior of the injection nozzles creates a non-uniformity in the flame front and therefore a disruptive interference of the acoustic oscillations.

[0067] Although the invention has been explained in relation to its preferred embodiments as mentioned above, it is to be understood that many other possible modifications and variations can be made without departing from the scope of the appended claims.

Claims

1. A combustor unit (10) for a gas turbine assembly (1) comprising a premix combustor (15) and a reheat combustor (16), which are arranged in series along the gas flow direction (M); the reheat combustor (16) comprising:

   a housing (20) extending substantially along a longitudinal axis (B) and defining a reheat combustion chamber (23),
   a plurality of injection units (27) distributed around the reheat combustion chamber (23) and fed with air and fuel;
   at least one first injection unit (27a) of the plurality of injection units (27) being configured to inject fuel and air differently with respect to the others injection units (27b, 27c, 27d, 27e).

2. A combustor unit according to claim 1, wherein all the injection units (27a, 27b, 27c, 27d, 27e) of the

plurality of injection units (27) are configured to inject fuel and air differently from each other.

3. A combustor unit according to claim 1 or 2, wherein the at least one first injection unit (27a) of the plurality of injection units (27) is configured to inject fuel and air according to a different equivalence ratio and/or to a different mixing between air and fuel and/or to a different penetration into the reheat combustion chamber (23) with respect to the other injection units (27b, 27c, 27d, 27e).

4. A combustor unit according to anyone of the foregoing claims, wherein the geometry of the at least one first injection unit (27a) of the plurality of injection units (27) is different from the geometry of the other injection units (27b, 27c, 27d, 27e) of the plurality of injection units (27).

5. **A** combustor unit according to anyone of the foregoing claims, wherein the amount of air and/or fuel fed to the at least one first injection unit (27a) of the plurality of injection units (27) is different from the amount of air and/or fuel fed to the other injection units (27b, 27c, 27d, 27e) of the plurality of injection units (27).

6. **A** combustor unit according to anyone of the foregoing claims, wherein each injection unit (27a, 27b, 27c, 27d) of the plurality of injection units (27) engages a respective hole (28) of the housing (20).

7. A combustor unit according to anyone of the foregoing claims, wherein each injection unit (27a, 27b, 27c, 27d) of the plurality of injection units (27) comprises a fuel supply line (30) and at least one fuel nozzle (31) in fluidic communication with the fuel supply line (30); an air supply line (29) and at least one air nozzle (32) in fluidic communication with the air supply line (31); and a conveying tube (33) extending along an extension axis (C) and provided with an outlet (35) flowing into the reheat combustion chamber (23); in the conveying tube (33) air and fuel coming from the at least one fuel nozzle (31) and air nozzle (32) are mixed.

8. A combustor unit according to claim 7, wherein the inlet of the conveying tube (33) coincides with the air nozzle (32) .

9. A combustor unit according to claim 7 or 8, wherein the at least one first injection unit (27a) has a conveying tube (33a) having a first tube length (La) different from the tube lengths (Lb, Lc, Ld, Le) of the conveying tubes (33b, 33c, 33d, 33e) of the other injection units (27b, 27c, 27d, 27e).

10. A combustor unit according to anyone of claims 7-9, wherein at least one first fuel nozzles (31a) of the at least one first injection unit (27a) has a first diameter (Da) different from the diameters (Db, Dc, Dd, De) of the fuel nozzles (31b, 31c, 31d, 31e) of the other injection units (27b, 27c, 27d, 27e).

11. A combustor unit according to anyone of claims 7-10, wherein the at least one first injection unit (27a) has a first conveying tube (33a) having a first tube width (Wa) different from the tube widths (Wb, Wc, Wd, We) of the conveying tubes (33b, 33c, 33d, 33e) of the other injection units (27b, 27c, 27d, 27e).

12. A combustor unit according to anyone of claims 7-11, wherein the at least one first injection unit (27a) has a first air nozzle (32a) having a passage section (Aa) different from the passage sections (Ab, Ac, Ad, Ae) of the air nozzles (32b, 32c, 32d, 32e) of the other injection units (27b, 27c, 27d, 27e).

13. A combustor unit according to claim 12, wherein the first injection unit (27a) comprises a metering plate (39) provided with a hole (40) and coupled to the first air nozzle (32a) to adjust the passage section (Aa) of the first air nozzle (32a).

14. A combustor unit according to anyone of claims 7-13, wherein the at least first injection unit (27a) has a first conveying tube (33a) extending along an extension axis (C) which is inclined differently from the extension axes (C) of the conveying tubes (33a, 33b, 33c, 33d, 33e) of the other injection units (27b, 27c, 27d, 27e).

15. Gas turbine assembly comprising:
a compressor (2), a turbine (4) and a combustor assembly (3); the combustor assembly (3) comprising at least one combustor unit (10) as claimed in anyone of the foregoing claims.

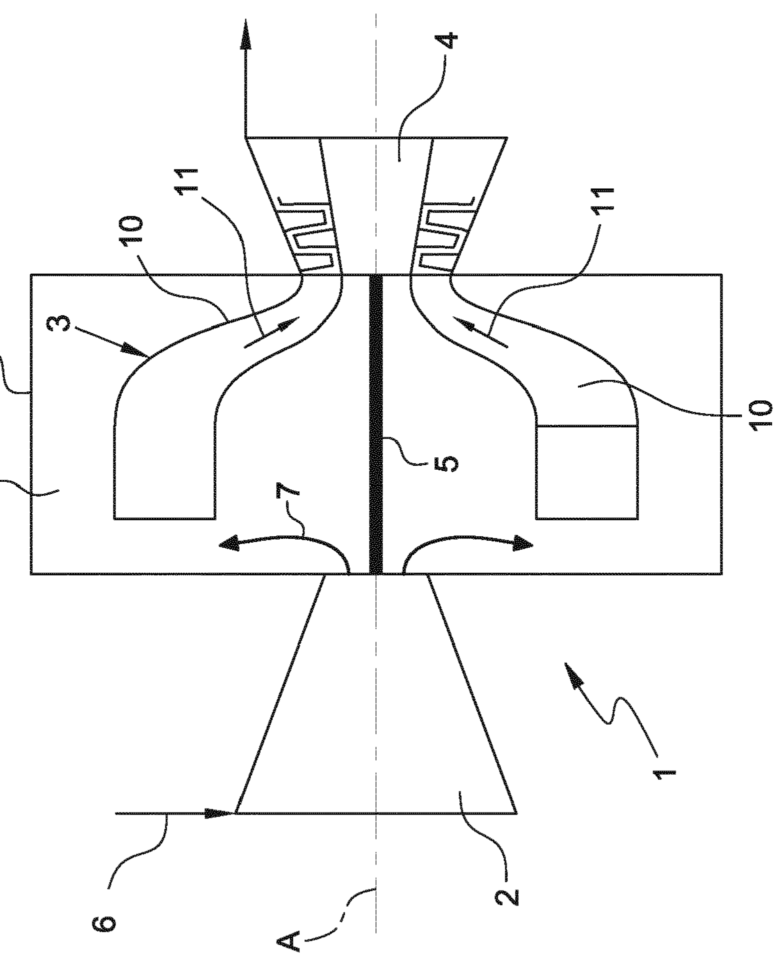

FIG. 1

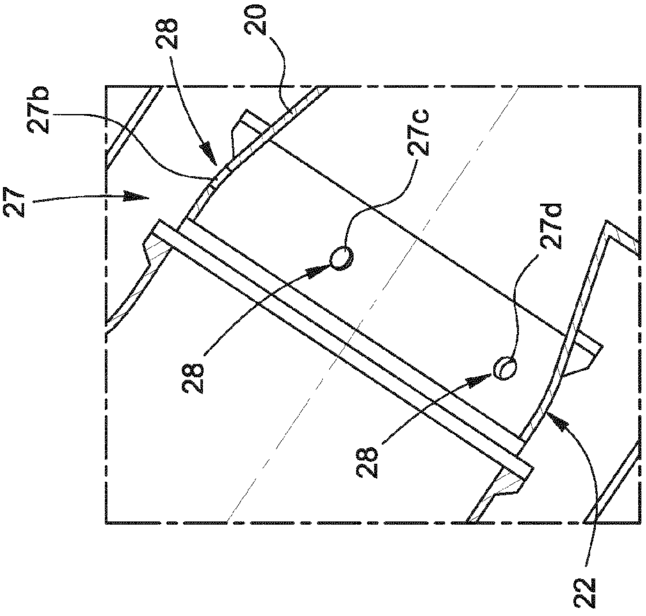

FIG. 2b

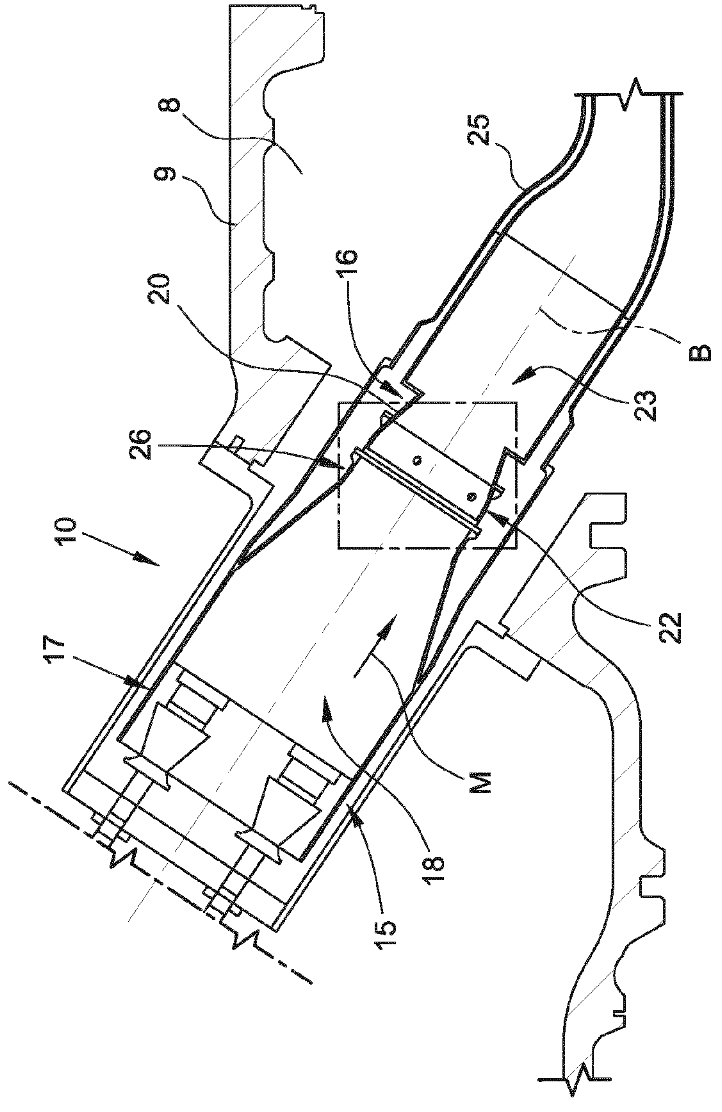

FIG. 2a

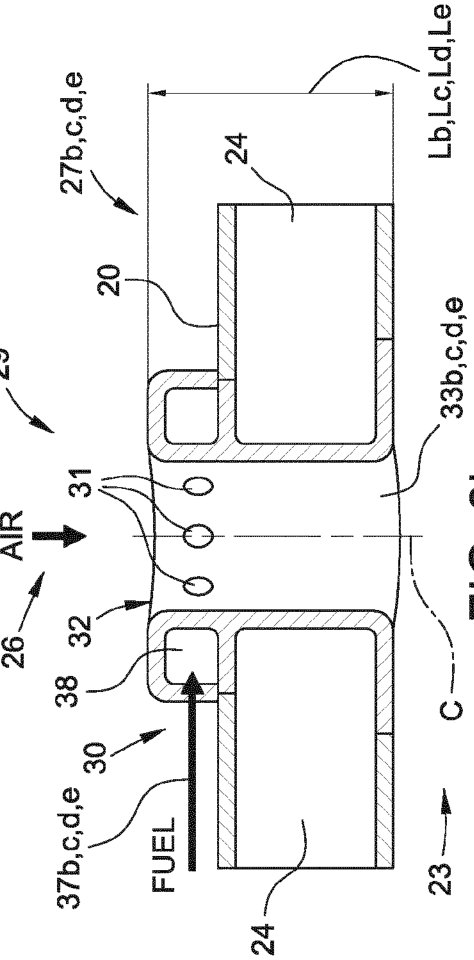

FIG. 3b

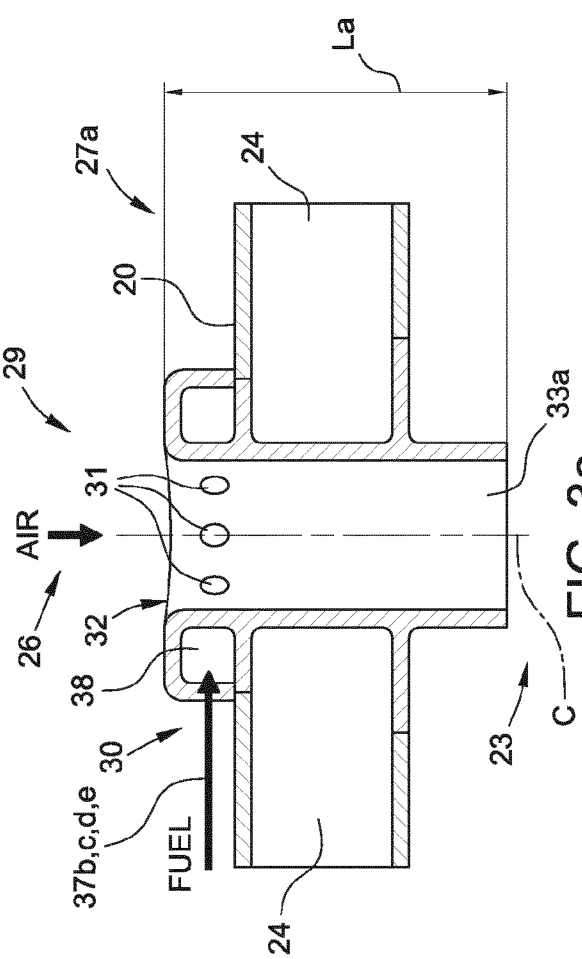

FIG. 3c

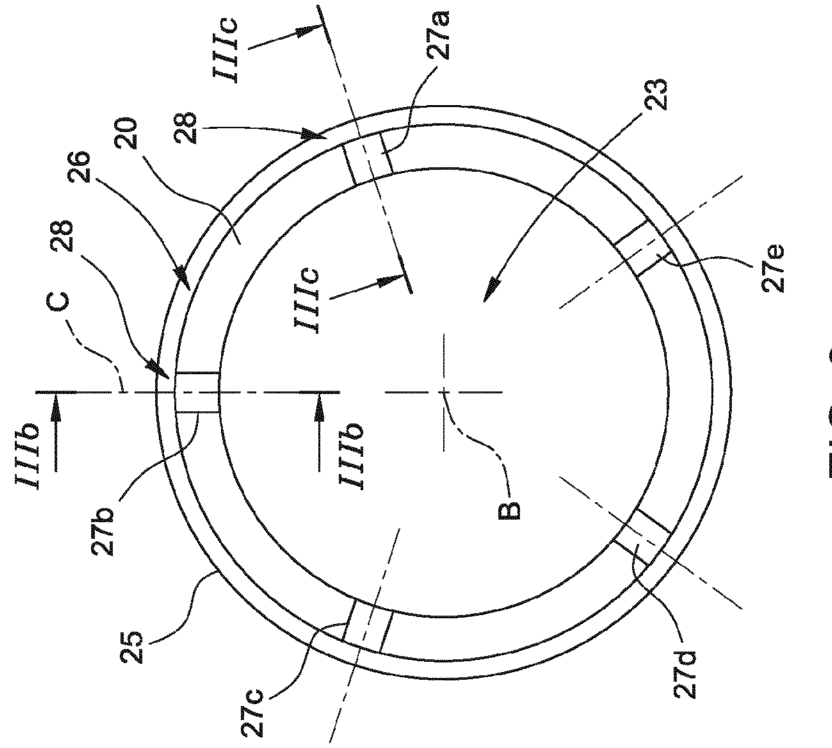

FIG. 3a

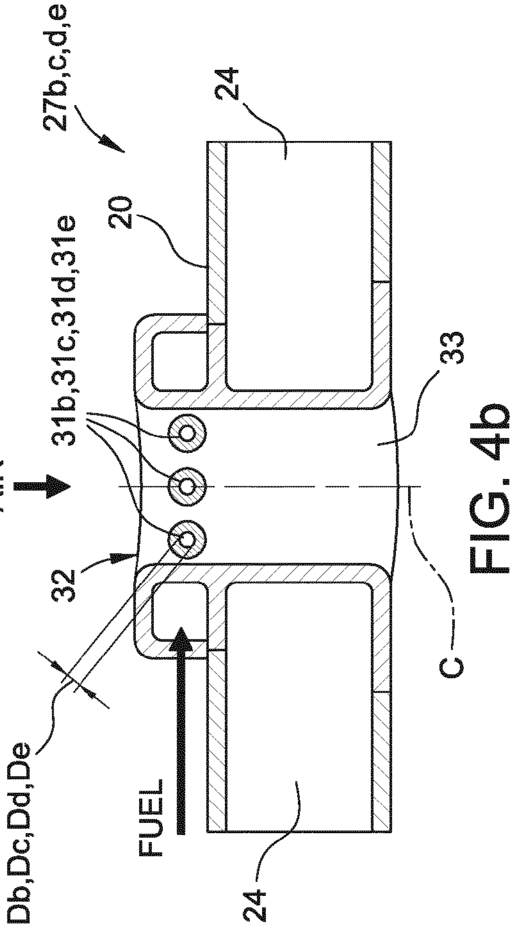

FIG. 4b

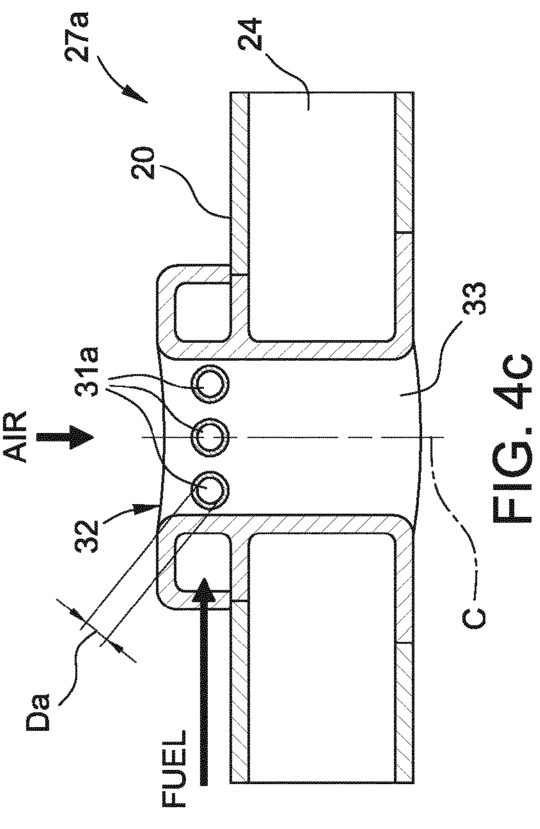

FIG. 4c

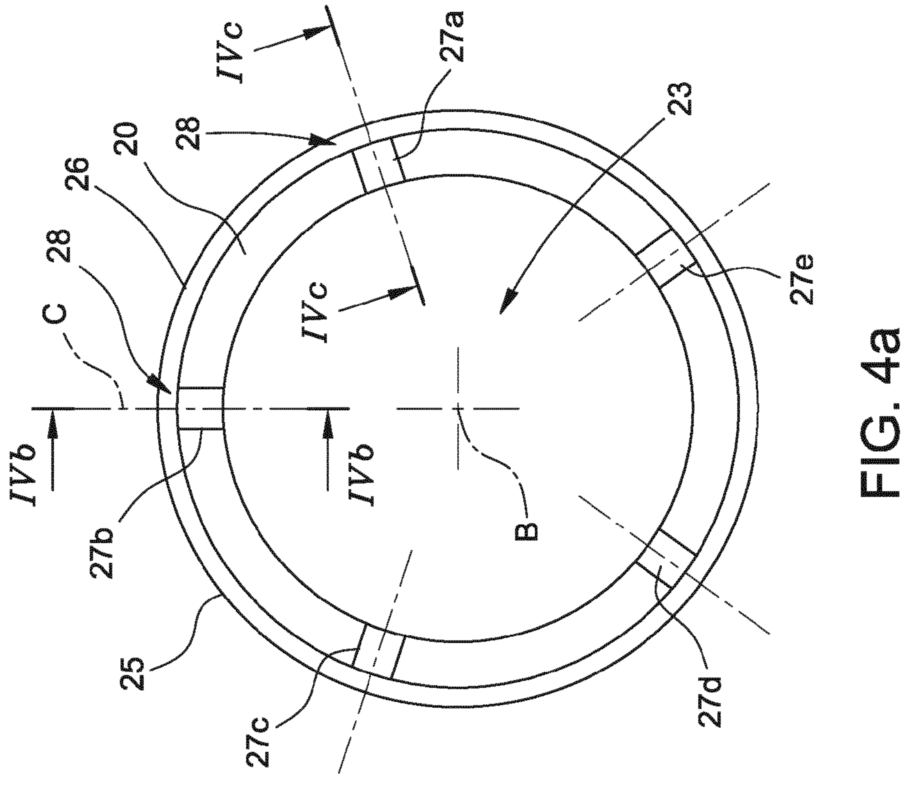

FIG. 4a

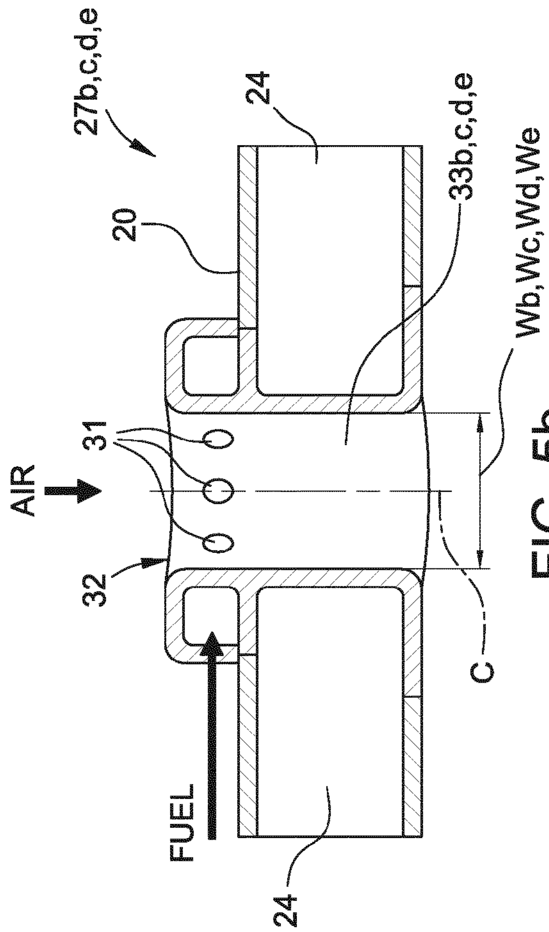

FIG. 5b

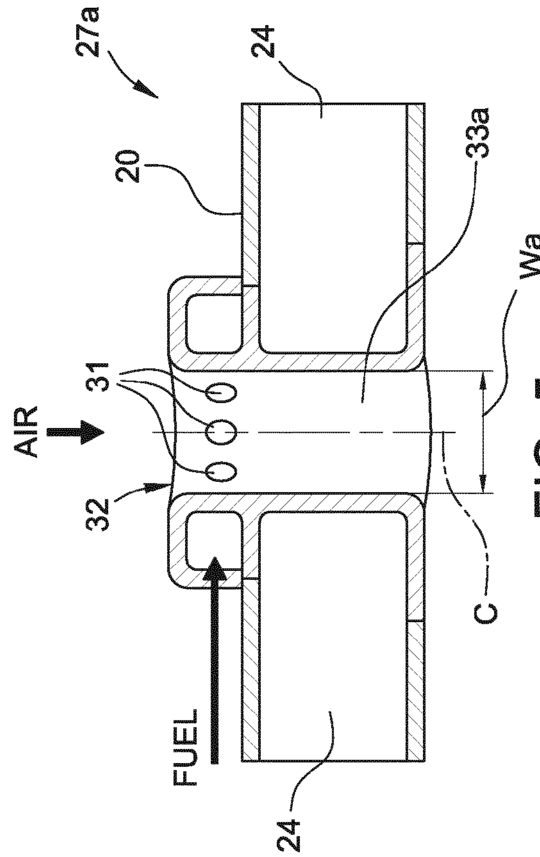

FIG. 5c

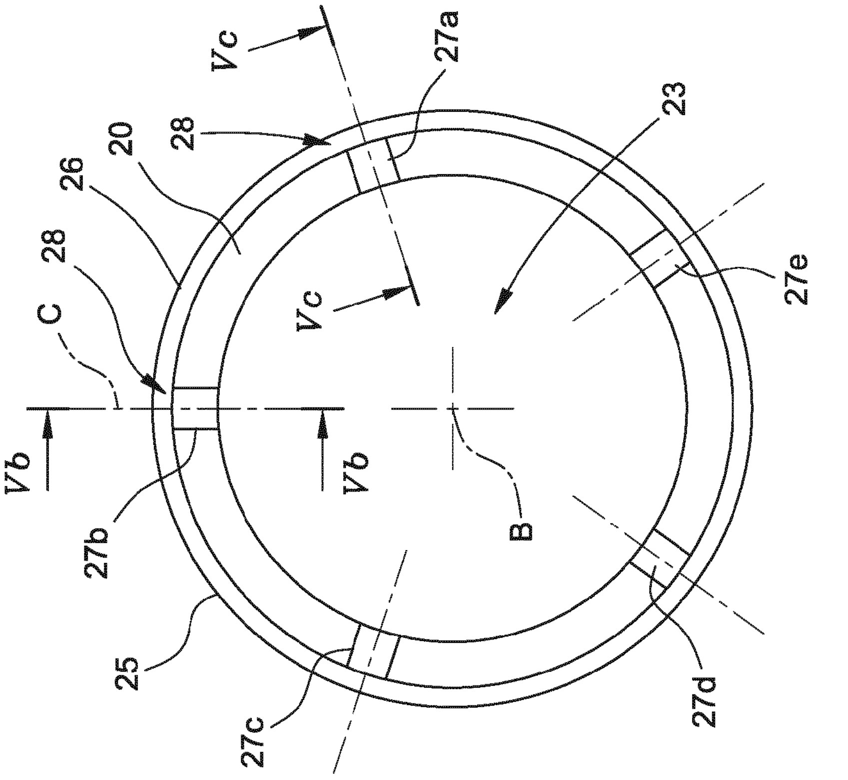

FIG. 5a

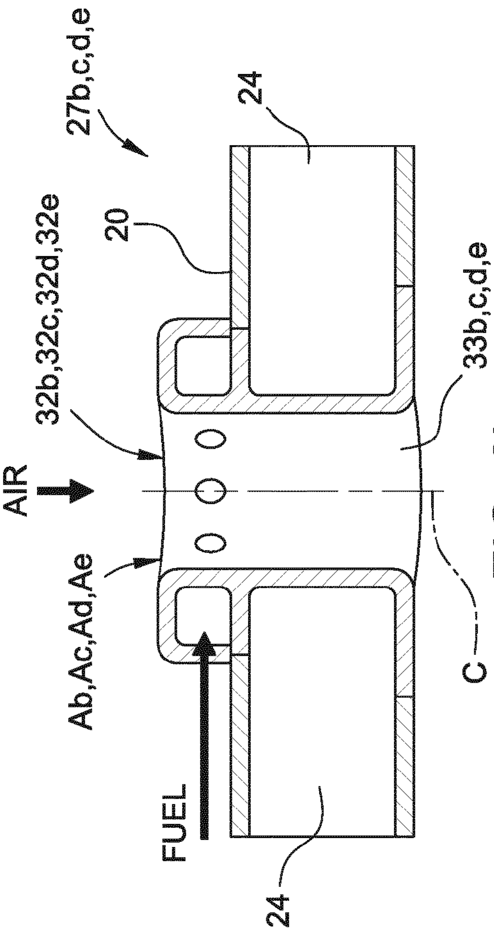

FIG. 6b

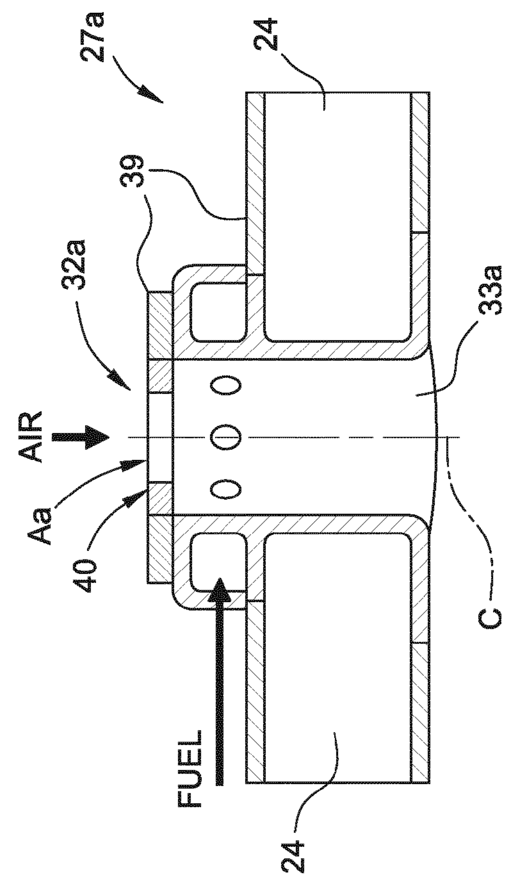

FIG.6c

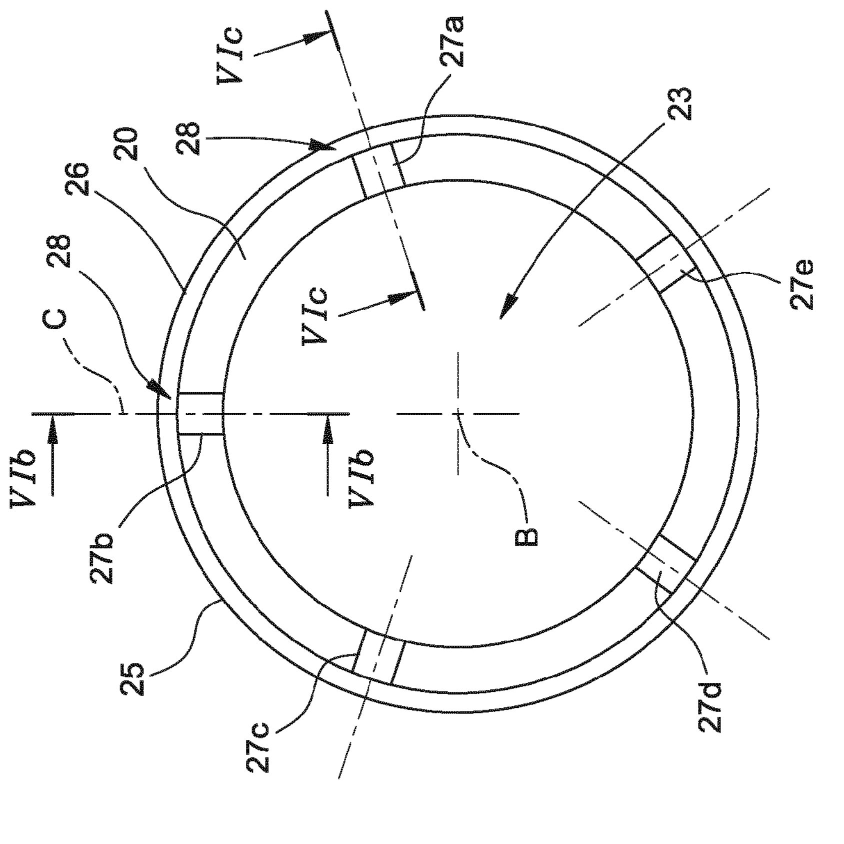

FIG. 6a

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EUROPEAN SEARCH REPORT

Application Number
EP 20 21 7211

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	EP 2 835 516 A1 (ALSTOM TECHNOLOGY LTD [CH]) 11 February 2015 (2015-02-11) * paragraphs [0036], [0040]; figure 3 *	1,3,5,15 4,6-14	INV. F23R3/28 F23R3/34
X	EP 3 486 568 A1 (ANSALDO ENERGIA SWITZERLAND AG [CH]) 22 May 2019 (2019-05-22) * paragraphs [0019], [0021], [0030], [0044] - [0049]; figures 2-7,10 *	1-3,5,15	
Y A	US 2016/305337 A1 (CROTHERS SARAH LORI [US] ET AL) 20 October 2016 (2016-10-20) * paragraphs [0031], [0034], [0035], [0038]; figure 3 *	4,6, 9-12,14 1,15	
Y A	US 2020/378604 A1 (ROH U JIN [KR]) 3 December 2020 (2020-12-03) * paragraphs [0077], [0079], [0095], [0096]; figures 2,4,7,8 *	6-14 1,15	
A	WO 2013/022367 A1 (GEN ELECTRIC [US]; STRYAPUNIN SERGEY ALEKSANDROVICH [RU]) 14 February 2013 (2013-02-14) * page 18, line 16 - page 21, line 2; figures 3-14 *	1,4,7-9, 14,15	TECHNICAL FIELDS SEARCHED (IPC) F23R
A	EP 3 369 995 A1 (ANSALDO ENERGIA SWITZERLAND AG [CH]) 5 September 2018 (2018-09-05) * paragraphs [0004] - [0010], [0014] - [0016]; figures 2-8 *	1-15	
A	WO 2009/078891 A2 (SIEMENS ENERGY INC [US]; PARKER DAVID M [US] ET AL.) 25 June 2009 (2009-06-25) * paragraphs [0017], [0018]; figures 2,3 *	1-15	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	2 June 2021	Mougey, Maurice

CATEGORY OF CITED DOCUMENTS

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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02-06-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2835516 A1	11-02-2015	CN 104373219 A	25-02-2015
		EP 2835516 A1	11-02-2015
		EP 2843211 A1	04-03-2015
		JP 5865968 B2	17-02-2016
		JP 2015034548 A	19-02-2015
		KR 20150018451 A	23-02-2015
		US 2015040573 A1	12-02-2015
EP 3486568 A1	22-05-2019	CN 110030580 A	19-07-2019
		EP 3486568 A1	22-05-2019
		US 2019154263 A1	23-05-2019
US 2016305337 A1	20-10-2016	CN 106196173 A	07-12-2016
		DE 102016106984 A1	20-10-2016
		GB 2539082 A	07-12-2016
		JP 6774208 B2	21-10-2020
		JP 2016205808 A	08-12-2016
		US 2016305337 A1	20-10-2016
US 2020378604 A1	03-12-2020	KR 102138013 B1	27-07-2020
		US 2020378604 A1	03-12-2020
WO 2013022367 A1	14-02-2013	CN 103717971 A	09-04-2014
		EP 2742291 A1	18-06-2014
		US 2013174558 A1	11-07-2013
		WO 2013022367 A1	14-02-2013
EP 3369995 A1	05-09-2018	CN 108534137 A	14-09-2018
		EP 3369995 A1	05-09-2018
		US 2018252412 A1	06-09-2018
WO 2009078891 A2	25-06-2009	EP 2185870 A2	19-05-2010
		JP 5020379 B2	05-09-2012
		JP 2010539438 A	16-12-2010
		KR 20100061538 A	07-06-2010
		WO 2009078891 A2	25-06-2009

EPO FORM P0459

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