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(54) BURNER ASSEMBLY WITH IN-LINE INJECTORS

(57) A burner assembly for a heavy-duty gas turbine engine has a main burner (15), extending around a burner axis (B) and including: a swirler (7), having a plurality of blades (24) circumferentially distributed around the burner axis (B), wherein mixing channels (25) are defined between respective pairs of adjacent blades (24); a plurality of in-line injectors (35), arranged at inlet sections of respective mixing channels (25) and having respective in-line nozzles (36), configured to discharge in a respective flow direction (F) of a fluid flowing through the respective mixing channel (25) .

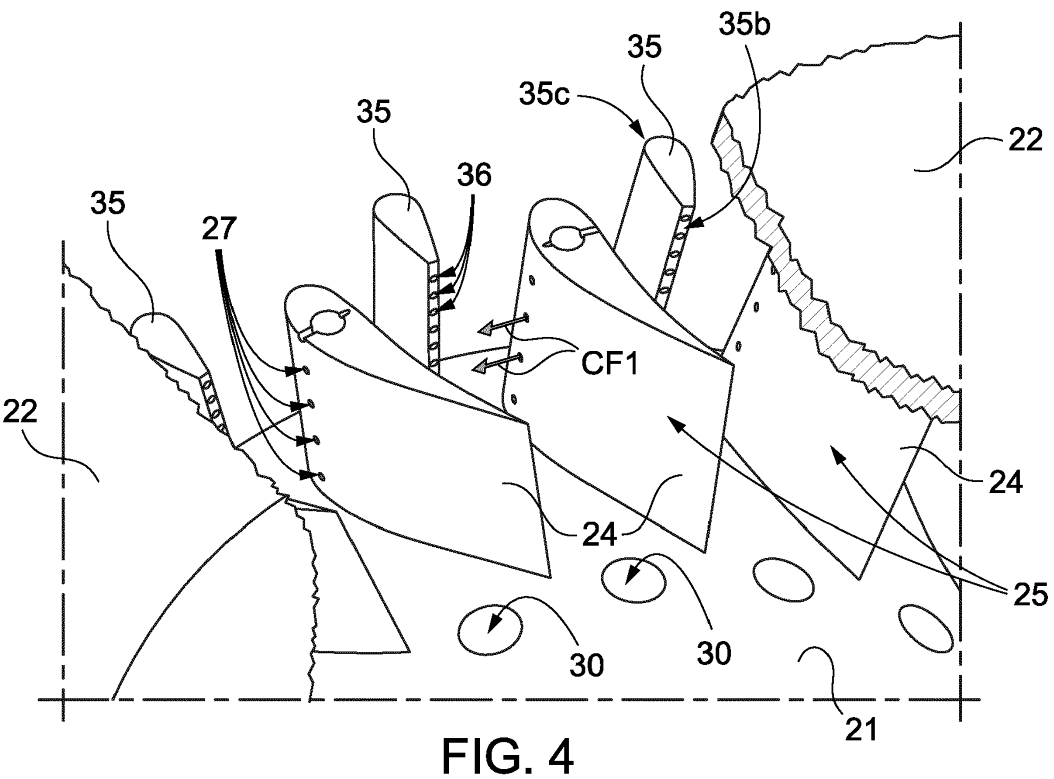


FIG. 4

Description

TECHNICAL FIELD

[0001] The present invention relates to a burner assembly with in-line injectors.

BACKGROUND

[0002] As already known, gas turbine engines, especially if used in electric power production plants, may be fed with different types of fuel. In particular, it is known that fuel gas of different nature and characteristics (natural gas, syngas) or fuel oils like diesel fuel can be injected into gas turbines. Recently, the need to cope with requirements for reducing pollutant emissions has led to develop gas turbine engine that accept also hydrogen. For this reason, gas turbines engines are equipped with burner assemblies having multiple injectors or burners. Axial lance injectors, specifically designed to deliver fuel oil, extend along a burner axis. Axial pilot burners, of premix or diffusion type, extend around the lance injectors and are usually run on fuel gas, such as natural gas or syngas, fuel oil, or hydrogen. So-called premix diagonal burners have frustoconical shape and are arranged around the respective pilot burners. The diagonal burners may be supplied with any of fuel oil, fuel gas or hydrogen. More specifically, a premix diagonal burner has a plurality of swirl blades that define mixing channels and cause a rotation around the burner axis of air flowing therethrough. Fuel feed passages extend radially trough the blades and discharge into the mixing channels through outlets in the lateral faces (intrados and/or extrados) of the blades. Crossflow fuel injection is thus achieved. While crossflow injection is beneficial when gas is supplied, because efficient mixing of air and fuel is obtained, problem may rise when highly reactive fuels such as hydrogen are used. In fact, the kind of vortices specifically associated with crossflow injection may cause low velocity regions and possibly recirculation, which increase the risk of flame holding or flashback. Also, crossflow injection is sensitive to momentum flux ratio changes also associated with a fuel with different Wobbe Index.

SUMMARY OF THE INVENTION

[0003] It is thus an object of the present invention to provide a burner assembly that allows to overcome or at least attenuate the above described limitations.

[0004] According to the present invention, there is provided a burner assembly for a heavy-duty gas turbine engine comprising a main burner, extending around a burner axis and including:

- a swirler, having a plurality of blades circumferentially distributed around the burner axis, wherein mixing channels are defined between respective pairs of adjacent blades;
- a plurality of in-line injectors, arranged at inlet sections of respective mixing channels and having respective in-line nozzles, configured to discharge in a respective flow direction of a fluid flowing through the respective mixing channel.

[0005] The in-line injectors are configured to deliver fuel substantially in the flow direction of air entering the mixing channels and avoid vortices which are normally associated with crossflow injection and may result in low velocity regions. Thus, flow velocity is not disturbed the risk of flame hold or flashback is reduced when highly reactive fuels like hydrogen are used. As the in-line injectors are located at the inlet of the mixing channels, substantially the whole length thereof is available to achieve sufficient mixing, so greater mixing effect associated with crossflow flow injection is not necessary.

[0006] According to an aspect of the invention, the in-line injectors comprise respective airfoil-shaped posts with a trailing edge, wherein the in-line nozzles discharge at the respective trailing edge.

[0007] Therefore, the air flow entering the mixing channels is not disturbed by the shape of the in-line injectors or by the delivery of fuel

[0008] According to an aspect of the invention, the in-line nozzles are configured to discharge along a tangent to a camber line of the respective in-line injector at the trailing edge.

[0009] The delivered fuel flow is thus consistent in direction with the air flow entering the mixing channels and turbulence that may cause drop of velocity is avoided.

[0010] According to an aspect of the invention, lateral surfaces of the in-line injectors form lobes at least at the trailing edge and/or are provided with vortex generators, arranged upstream of the respective trailing edge and configured to swirl the flow.

[0011] Features may be added to the trailing edge and/or the lateral surfaces of the in-line injectors if greater mixing rate is desired. Lobes and vortex generators may be designed to cause a swirl around the average flow direction, without causing recirculation or stagnation of the flow. Sufficient flow velocity may thus me preserved at any location to prevent flame hold and flashback when highly reactive fuels are used.

[0012] According to an aspect of the invention, the main burner comprises an inner body, having a frustoconical outer surface, and an outer body, having a frustoconical inner surface, wherein an annular space is defined between the frustoconical outer surface of the inner body and the frustoconical inner surface of the outer body and wherein the blades extend in the annular space, the inner body being preferably monolithic.

[0013] The burner assembly thus includes several burners that allow operation on multiple fuels, including hydrogen, and are also flexible enough to cope with a wide range of operating conditions as currently required by market and regulatory authorities. The monolithic inner body prevents any leakage from the hydrogen plenum, which may otherwise occur because of ageing of seals or native defects.

[0014] According to an aspect of the invention, the burner assembly comprises a first plenum integrated in the inner body and fluidly coupled to the in-line nozzles of the in-line injectors.

[0015] According to an aspect of the invention, the blades are provided with respective first crossflow nozzles, configured to discharge into the mixing channels of the respective blades in a first crossflow direction, transverse to the flow direction, through lateral surfaces of the respective blades.

[0016] According to an aspect of the invention, the burner assembly comprises a second plenum fluidly coupled to the first crossflow nozzles and fluidly decoupled from the in-line nozzles, wherein the first plenum is fluidly decoupled from the first crossflow nozzles, the second plenum being preferably integrated in the inner body.

[0017] According to an aspect of the invention, the burner assembly comprises second crossflow nozzles in the frustoconical outer surface of the inner body, configured to discharge in a second crossflow direction, transverse to the flow direction and preferably distinct from the first crossflow direction.

[0018] According to an aspect of the invention, the burner assembly comprises a third plenum fluidly coupled to the second crossflow nozzles and fluidly decoupled from the in-line nozzles, wherein the first plenum is fluidly decoupled from the second crossflow nozzles, the third plenum being preferably integrated in the inner body.

[0019] Additional crossflow nozzles and plena allow to optimize separate and decoupled delivery paths for supply of additional kinds of fuels other than hydrogen, such as fuel gas and fuel oil.

[0020] According to an aspect of the invention, the in-line injectors are arranged so as to discharge upstream of the first crossflow nozzles of the blades defining the respective mixing channels.

[0021] Besides exploiting the whole length of the mixing channels, injection discharge upstream of the first crossflow nozzles has the advantage that the fuel flow delivered may help breaking and cross low velocity regions.

[0022] According to an aspect of the invention, the in-line injectors extend from the inner body into the annular space, preferably each at a median plane of the respective mixing channel.

[0023] According to an aspect of the invention, the burner assembly comprises a pilot burner, coaxially housed in the main burner, and a lance injector extending along the burner axis through the pilot burner.

[0024] According to the present invention, there is also provided a gas turbine engine comprising a combustor equipped with a plurality of burner assemblies according to any one of the preceding claims and a hydrogen supply line, fluidly coupled to the in-line injectors.

[0025] According to an aspect of the invention, the gas turbine engine comprises a fuel oil supply line and a fuel gas supply line, each fluidly coupled to at least one of the pilot burner and the lance injector.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The present invention will now be described with reference to the accompanying drawings, which illustrate some non-limitative embodiments thereof, in which:

- figure 1 is a simplified block diagram of a gas turbine engine;
- figure 2 is a cross-sectional lateral view of a burner assembly of the gas turbine engine of figure 1, in accordance with an embodiment of the present invention;
- figure 3 is an enlarged detail of figure 2;
- figure 4 is a perspective view of a detail of the burner assembly of figure 2, with parts removed for clarity;
- figure 5 is a perspective view of a further enlarged detail of the burner assembly of figure 2;
- figure 6 is a front view of a detail of a burner assembly in accordance with a different embodiment of the present invention;
- figure 7 is a front view of a detail of a burner assembly in accordance with another embodiment of the present invention; and
- figure 8a, 8b, 9a, 9b are graphs showing quantities used in the gas turbine engine of figure 1.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0027] With reference to figure 1, a heavy-duty gas turbine engine is indicated as a whole by reference numeral 1 and comprises a compressor 2, a combustor 3, a turbine 5 a fuel supply system 6 and a control system 7.

[0028] The compressor 2 and the turbine 5 are mounted to a same shaft, which extends along a main axis A.

[0029] In the embodiment described herein, the combustor 3 is of the annular type and is arranged about the main axis A between the compressor 2 and the turbine 5. However, this must not be considered limitative, as the invention may be advantageously used also with combustion chambers of different type, in particular of the silo type. The combustor 3 comprises a plurality of burner assemblies 10, which are circumferentially distributed around the axis A, and an annular combustion chamber 11 (part of which is visible in figure 2). The burner assemblies 10 are mounted to respective burner seats of the combustor 3 by respective burner inserts 12.

[0030] The fuel supply system 6 is configured to supply different types of fuel to the combustor 3, including fuel oil, fuel gas, such as natural gas or syngas, and highly reactive fuel, namely fuel with high hydrogen content and simply identified as hydrogen in what follows for the sake of simplicity. A fuel oil supply line 6a, a fuel gas supply line 6b and a hydrogen line 6c are provided for this purpose. At least the fuel gas supply line 6b and the hydrogen supply line 6c may be mutually connected e.g. by interconnection lines and control valves (see e.g. control valve 6d, figure 2), whereby the control system 7 is enabled to supply pure fuel gas or hydrogen or a mixture thereof in accordance with design preferences and circumstances. The proportion of fuel gas and hydrogen may be controlled as well.

[0031] The control system 7 defines a load set-point for the gas turbine engine 1 and operates engine actuators (orientable inlet guide vanes of the combustor 3 and fuel valves of the fuel supply system 6) to supply air and fuel flows to the combustor 3 so that the load set-point is met.

[0032] Figures 2 and 3 show in detail one of the burner assemblies 10 and a portion of the combustion chamber 11. The burner assembly 10 extends along an axis B and comprises a peripheral main burner 15, a central pilot burner 16 and a lance injector 17, all coaxially arranged about the burner axis B. More precisely, the pilot burner 16 is coaxially housed in the main burner 15 and the lance injector 17 extends along the burner axis B through the pilot burner 16.

[0033] In one embodiment, at least the main burner 15 and possibly also the pilot burner 16 and the lance injector 17 may receive all available types of fuel, i.e. fuel oil, fuel gas and hydrogen. In other embodiments, however, the main burner 15 may receive fuel gas and hydrogen only and the pilot burner 16 and the lance injector 17 may receive fuel oil and/or fuel gas only.

[0034] The main burner 15 is of the premix type, arranged about the pilot burner 16 and fixed to the respective burner insert 12. More in detail, the main burner 15 extends through a central opening 12a of the burner insert 12, so that the outlet of the main burner 15 is within the combustion chamber 11.

[0035] The main burner 15 is arranged around the pilot burner 4 and is provided with a vortex or turbulence generating device, referred to as diagonal swirler, and indicated by reference numeral 20. The diagonal swirler 20 extends about the burner axis B and is radially defined between an inner body 21 and an outer body 22 of the main burner 15. The inner body 21 has a frustoconical outer surface 21a and in one embodiment is a monolithic body, e.g. made by an additive manufacturing process such as SLM (Selective Laser Melting). The outer body 22 is axially hollow and comprises a frustoconical wall 22a and, in one embodiment, a cylindrical wall 22b connected to the frustoconical wall 22a by a joining portion 22c. The frustoconical wall 22a coaxially accommodates the inner body 21, so that a substantially annular space 23 forming a passage for feeding the air-fuel mixture is defined between a frustoconical inner surface 22d of the frustoconical wall 22a of the outer body 22 and the frustoconical outer surface 21a of the inner body 21.

[0036] As illustrated also in figures 3 and 4, the diagonal swirler 20 comprises a plurality of blades 24 which extend in the annular space 23 between the inner body 21 and the outer body 22 around the burner axis B. Pairs of adjacent blades 24 define respective mixing channels 25 and are configured to cause a rotation around the burner axis B of a fluid flowing through the mixing channels 25. Inlets of the mixing channels 25 are defined at a larger base of the frustoconical wall 22a of the outer body 22 and allow the introduction of an air flow from the compressor 2. The blades 24 are also provided with first crossflow nozzles 27 configured to discharge fuel gas and/or fuel oil in a first crossflow direction CF1, which is transverse to a flow direction F of fluid flowing through the mixing channels 25. To this end, a plenum 28 is formed in the inner body 22 and is fluidly coupled to one or both of the fuel oil supply line 6a and the fuel gas supply line 6b on one side and to the first crossflow nozzles 27 through built-in channels (not shown). Second crossflow nozzles 30 are formed in the frustoconical outer surface 21a of the inner body 21 and are configured to discharge fuel gas and/or fuel oil in a second crossflow direction CF2, transverse to the flow direction F and distinct from the first crossflow direction CF1. For example, the first crossflow direction CF1 may be a circumferential direction and the second crossflow direction CF2 may lie in a plane perpendicular to the first crossflow direction CF1.

[0037] A plenum 32, separate and isolated from the plenum 28, is formed in the inner body 21 and is fluidly coupled to one or both of the fuel oil supply line 6a and the fuel gas supply line 6b on one side and to the second crossflow nozzles 30.

[0038] With reference also to figures 3 and 4, the main burner 15 comprises also a plurality of in-line injectors 35, arranged at inlet sections of respective mixing channels 25 and have respective in-line nozzles 36, configured to discharge in a respective flow direction F of fluid flowing through the respective mixing channel 25. As herein understood, "in a respective flow direction F of fluid flowing through the respective mixing channel 25" means that, at the nozzles 36, the fuel delivered by the in-line injectors 35 has a component of velocity parallel to the velocity of the fluid that is greater than any component of velocity perpendicular to the velocity of the fluid. The position of the in-line nozzles 36 is upstream of the first crossflow nozzles 27 and may be upstream or inside an inlet portion the respective mixing channels 25. In other words, the in-line injectors 35 are arranged so as to discharge upstream of the first crossflow nozzles 27 of the blades 24 defining the respective mixing channels 25.

[0039] The in-line injectors 35 comprise respective airfoil-shaped posts 35a having a leading edge 35b and a trailing edge 35c and extending into the annular space 23 perpendicularly from the inner body 21 into the annular space (23). In one embodiment, the in-line injectors 35 are each at a median plane of the respective mixing channel 25. However, in other embodiments not illustrated, the in-line injectors 35 may be slightly displaced and/or oriented toward the suction side of the blade 24 defining the respective mixing channel 25.

[0040] The in-line nozzles 36 are arranged at the trailing edge 35c of the respective in-line injector 35 and discharge therethrough. An annular hydrogen plenum 40 is integrated in the inner body 21 and is fluidly coupled at least to the hydrogen line 6c and preferably to the fuel gas supply line 6b on one side and to the in-line nozzles 36 of the in-line injectors 35 on the other side, so that hydrogen or a mixture of hydrogen and fuel gas may be supplied to the main burner 15. More precisely, a chamber 41 extends longitudinally from a base portion to a tip portion of each in-line injector 35 (figure 4) and is coupled to the hydrogen plenum 40 through a passage in the inner body 21. Feed passages 42 extend from the chamber 41 to respective nozzles 36. In one embodiment, the flow direction F at the trailing edges 35c of the in-line injectors 35 is aligned with a tangent to a camber line C of the respective in-line injector at the trailing edge 35c (figure 5). The hydrogen plenum 40 may also receive fuel gas or a mixture of fuel gas and hydrogen in some operating conditions, such as during startup transients. A ratio of fuel gas and hydrogen may be controlled by the control system 7 in accordance with design preferences.

[0041] The plenum 28 and the plenum 32 are fluidly decoupled from the in-line nozzles 36; likewise, the hydrogen plenum 40 is fluidly decoupled from the first crossflow nozzles 27 and from the second crossflow nozzles 30. Accordingly, hydrogen leakage toward the first crossflow nozzles 27 and the second crossflow nozzles 30 is prevented. The plena 28, 32, 40 have respective fuel inlets at respective distinct angular positions. In figure 2 only the fuel inlet 40a of the hydrogen plenum 40 is shown.

[0042] In one embodiment, the trailing edges 35c of the in-line injectors are straight. In order to increase mixing rate, however, in another embodiment (figure 6) lateral surfaces of the in-line injectors 35 form lobes 35d at least at the trailing edge 35c. In still another embodiment (figure 7), the lateral surfaces of the in-line injectors 35 are provided with vortex generators 35e, arranged upstream of the respective trailing edge 35c (here straight) and configured to swirl the flow.

[0043] Fuel supply to the combustor 3 is controlled by the control system 7. For example, in one embodiment fuel supply is controlled to cause a step transition from fuel gas or fuel oil supply (dashed line) to hydrogen supply (solid line) or vice versa, as shown in figures 8a and 8b, respectively. In another embodiment, hydrogen supply is increased gradually (e.g. according to a ramp), while the other active fuel, fuel gas or fuel oil, is correspondingly decreased (figure 9a) or, vice versa, hydrogen supply is decreased while the other fuel to be activated, fuel gas or fuel oil, is correspondingly increased (figure 9b).

[0044] It is finally apparent that changes and variations may be made to the burner assembly described and illustrated without departing from the scope of protection of the accompanying claims.

[0045] For example, the plena may have any suitable configuration and arrangement whereby the hydrogen plenum is separated and decoupled from the other plena.

Claims

1. A burner assembly for a heavy-duty gas turbine engine comprising a main burner (15), extending around a burner axis (B) and including:

    a swirler (7), having a plurality of blades (24) circumferentially distributed around the burner axis (B), wherein mixing channels (25) are defined between respective pairs of adjacent blades (24);

    a plurality of in-line injectors (35), arranged at inlet sections of respective mixing channels (25) and having respective in-line nozzles (36), configured to discharge in a respective flow direction (F) of a fluid flowing through the respective mixing channel (25).

2. The burner assembly according to claim 1, wherein the in-line injectors (35) comprise respective airfoil-shaped posts (35a) with a trailing edge (35b), wherein the in-line nozzles (36) discharge at the respective trailing edge (35b).

3. The burner assembly according to claim 2, wherein the in-line nozzles (36) are configured to discharge along a tangent to a camber line (C) of the respective in-line injector (35) at the trailing edge (35b).

4. The burner assembly according to claim 2 or 3, wherein lateral surfaces of the in-line injectors (35) form lobes (35d) at least at the trailing edge (35b) and/or are provided with vortex generators (35e), arranged upstream of the respective trailing edge (35b) and configured to swirl the flow.

5. The burner assembly according to any one of the preceding claims, wherein the main burner (15) comprises an inner body (21), having a frustoconical outer surface (21a), and an outer body (22), having a frustoconical inner surface (22d), wherein an annular space (23) is defined between the frustoconical outer surface (21a) of the inner body (21) and the frustoconical inner surface (22d) of the outer body (22) and wherein the blades (24) extend in the annular space (23), the inner body (21) being preferably monolithic.

6. The burner assembly according to claim 5, comprising a first plenum (40) integrated in the inner body and fluidly coupled to the in-line nozzles (36) of the in-line injectors (35) .

7. The burner assembly according to claim 6, wherein the blades (24) are provided with respective first

crossflow nozzles (27), configured to discharge into the mixing channels (25) of the respective blades (24) in a first crossflow direction (CF1), transverse to the flow direction (F), through lateral surfaces of the respective blades (24).

8. The burner assembly according to claim 7, comprising a second plenum (28) fluidly coupled to the first crossflow nozzles (27) and fluidly decoupled from the in-line nozzles (36), wherein the first plenum (40) is fluidly decoupled from the first crossflow nozzles (27), the second plenum (28) being preferably integrated in the inner body (21).

9. The burner assembly according to claim 7 or 8, comprising second crossflow nozzles (30) in the frustoconical outer surface (21a) of the inner body (21), configured to discharge in a second crossflow direction (CF2), transverse to the flow direction (F) and preferably distinct from the first crossflow direction (CF1).

10. The burner assembly according to claim 9 dependent on claim 8, comprising a third plenum (32) fluidly coupled to the second crossflow nozzles (30) and fluidly decoupled from the in-line nozzles (36), wherein the first plenum (40) is fluidly decoupled from the second crossflow nozzles (30), the third plenum (32) being preferably integrated in the inner body (21).

11. The burner assembly according to any one of claims 5 to 10, wherein the in-line injectors (35) extend from the inner body (21) into the annular space (23), preferably each at a median plane of the respective mixing channel (25).

12. The burner assembly according to any one of the preceding claims, wherein the in-line injectors (35) are arranged so as to discharge upstream of the first crossflow nozzles (27) of the blades (24) defining the respective mixing channels (25).

13. The burner assembly according to any one of the preceding claims, comprising a pilot burner (21), coaxially housed in the main burner (15), and a lance injector (22) extending along the burner axis (B) through the pilot burner (21) .

14. A gas turbine engine comprising a combustor equipped with a plurality of burner assemblies (10) according to any one of the preceding claims and a hydrogen supply line (6c), fluidly coupled to the in-line injectors (35).

15. The gas turbine engine according to claim 14 dependent on claim 13, comprising a fuel oil supply line (6a) and a fuel gas supply line (6b), each fluidly coupled to at least one of the pilot burner (21) and the lance injector (17).

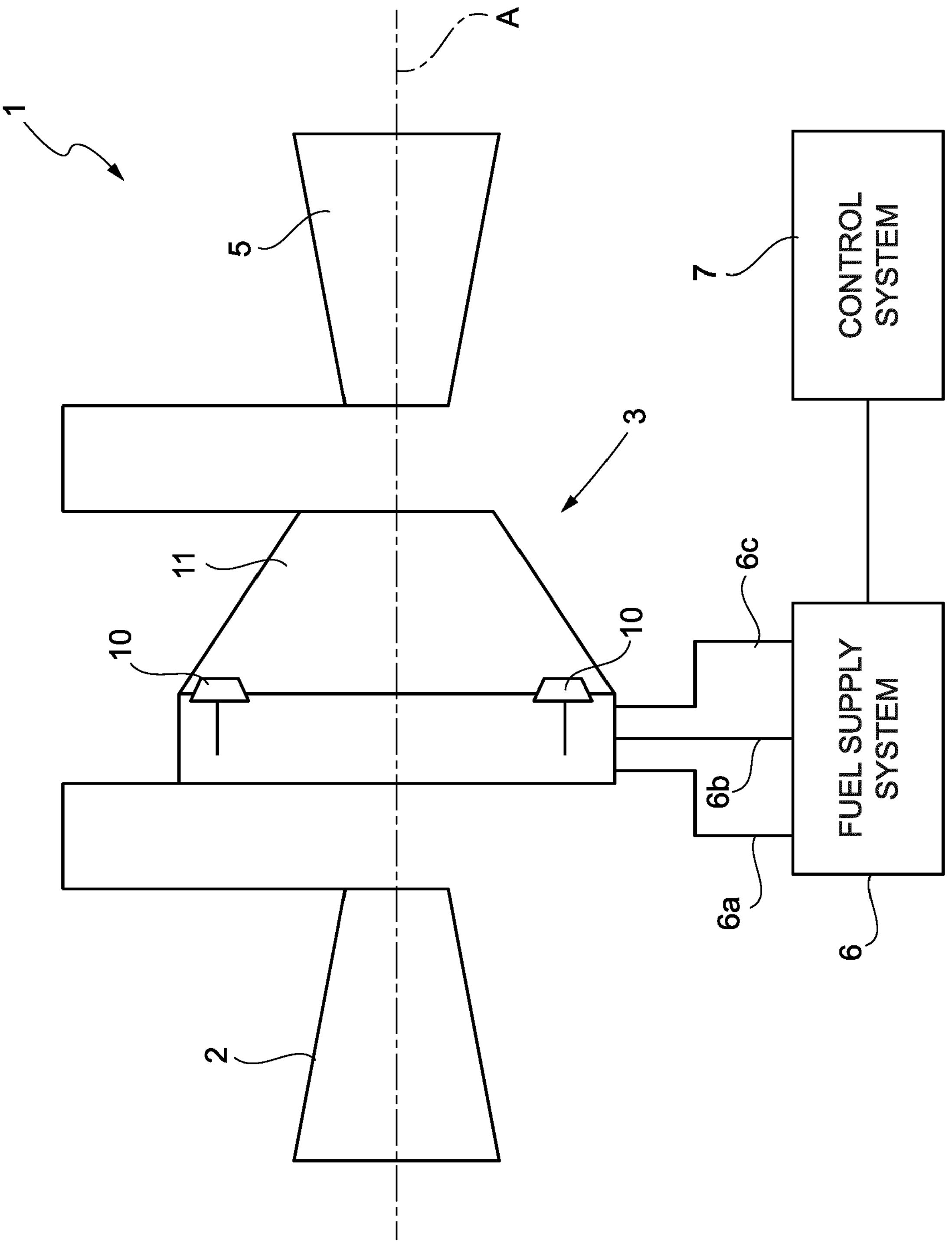
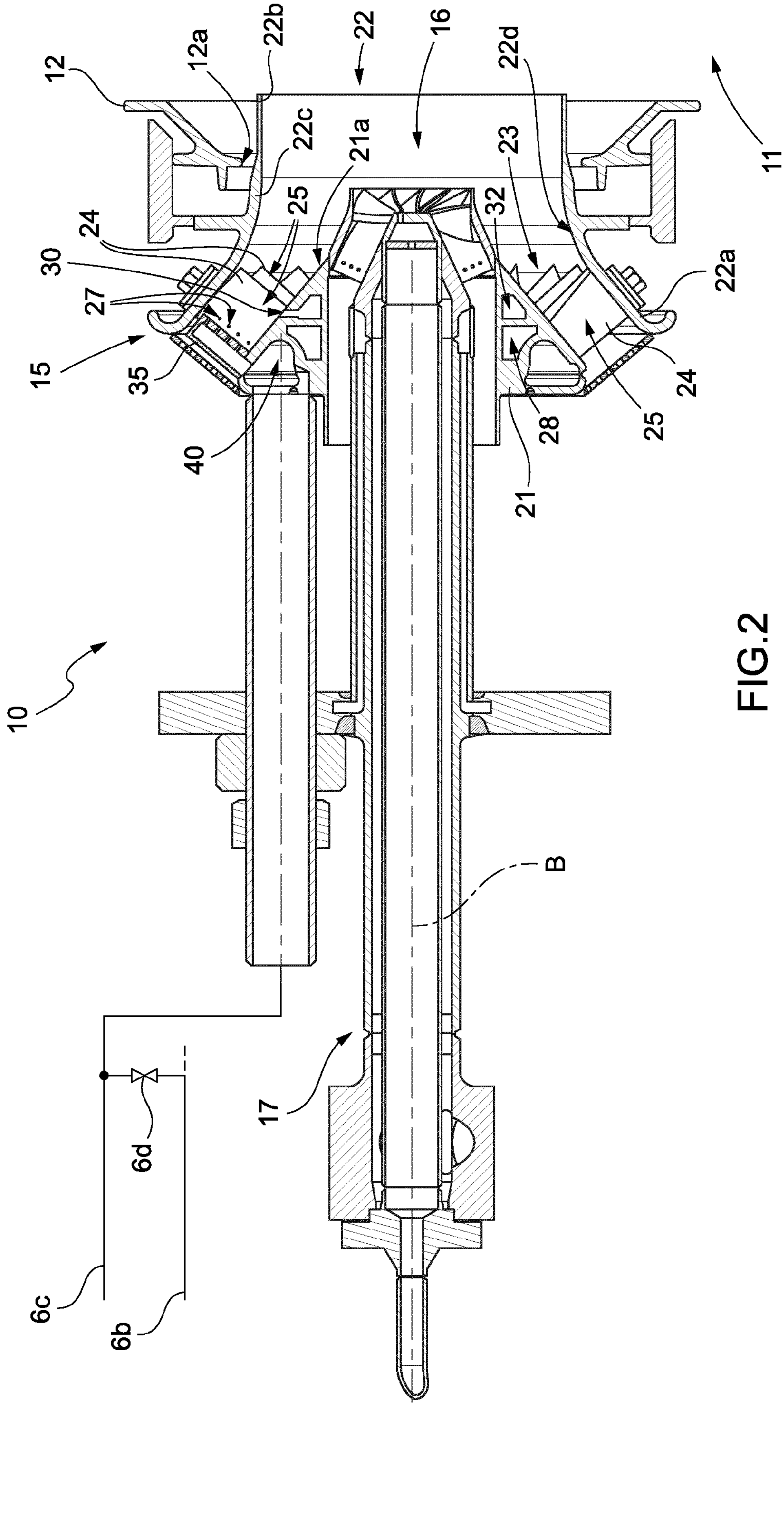


FIG. 1


12
12a
22b
22
16
22d
11
22c
21a
23
25
24
30
32
27
22a
15
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40
28
21
10
B
17
6d
6c
6b

FIG.2

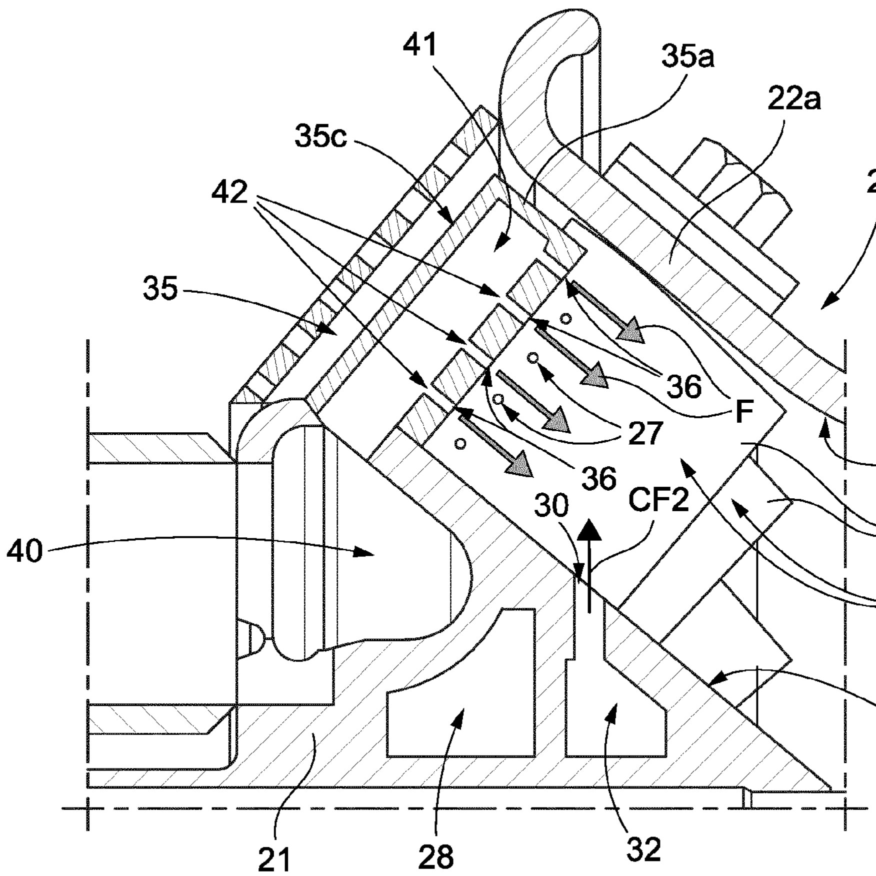
41
35a
22a
35c
22
42
35
36
F
27
22d
36
30
CF2
24
40
25
21a
21
28
32

FIG. 3

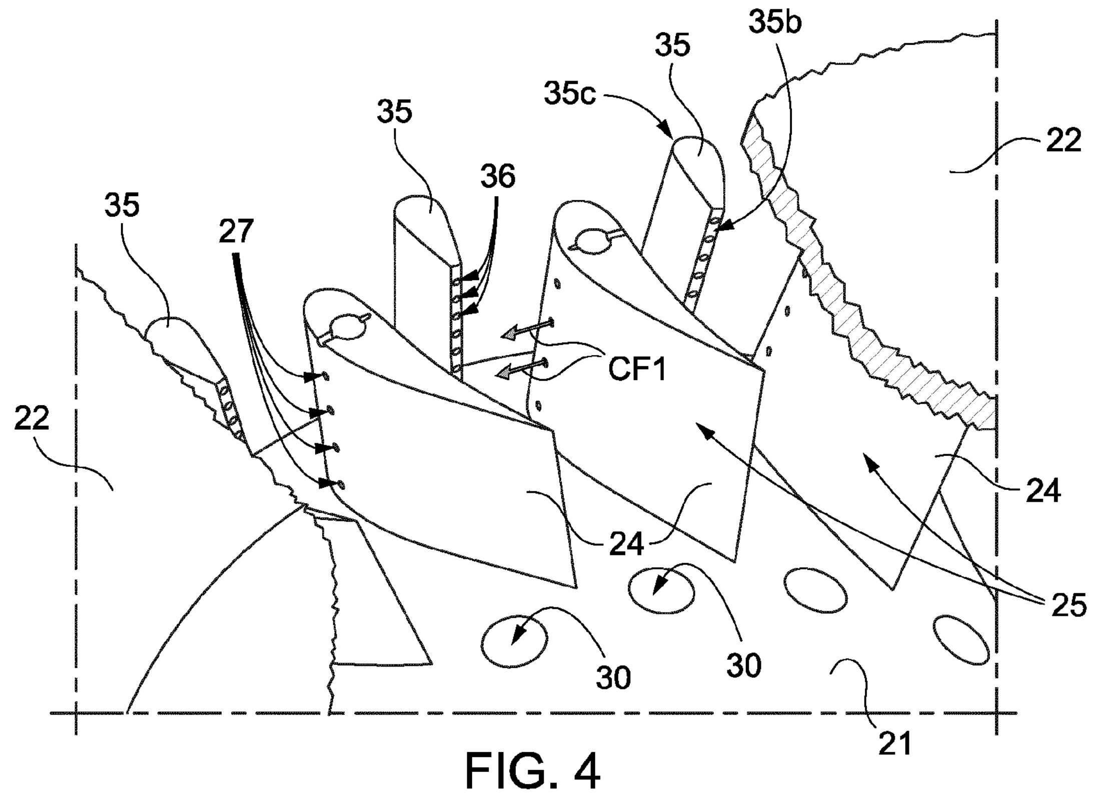
35b
35
35c
22
35
36
35
27
CF1
22
24
24
24
25
30
30
21

FIG. 4

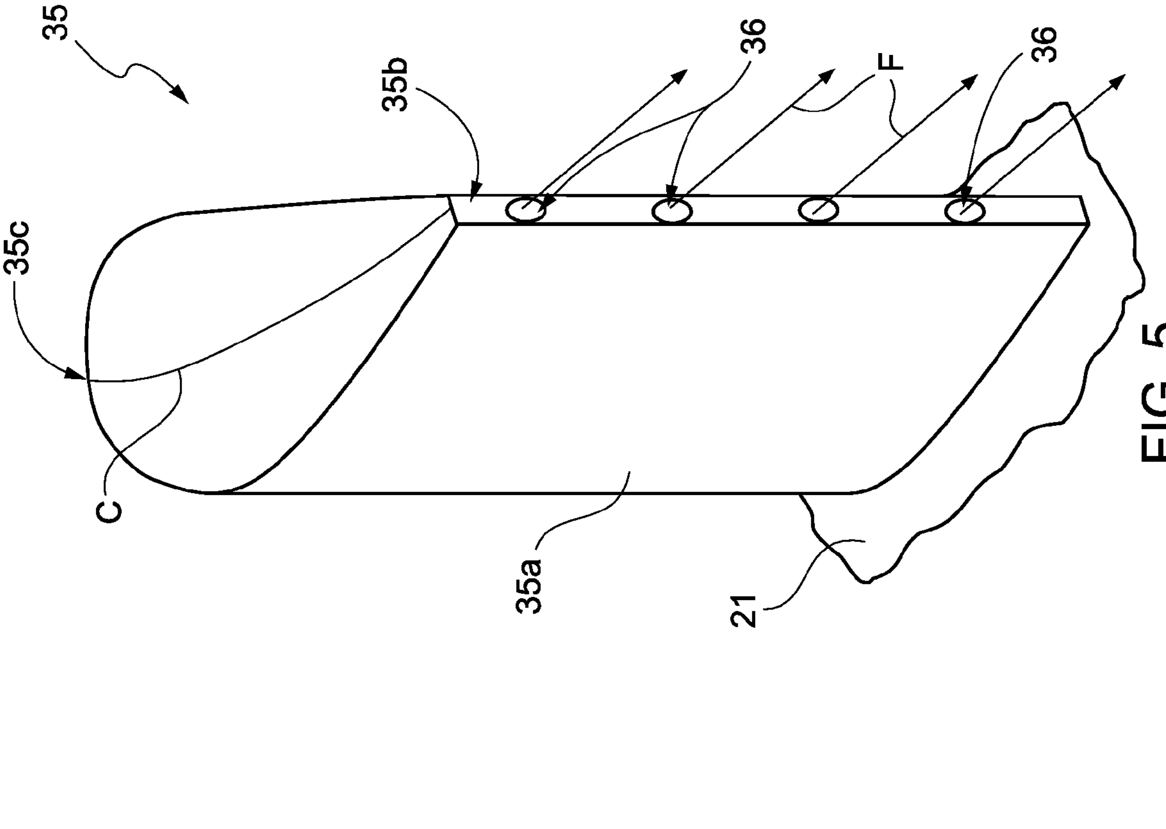

FIG. 5

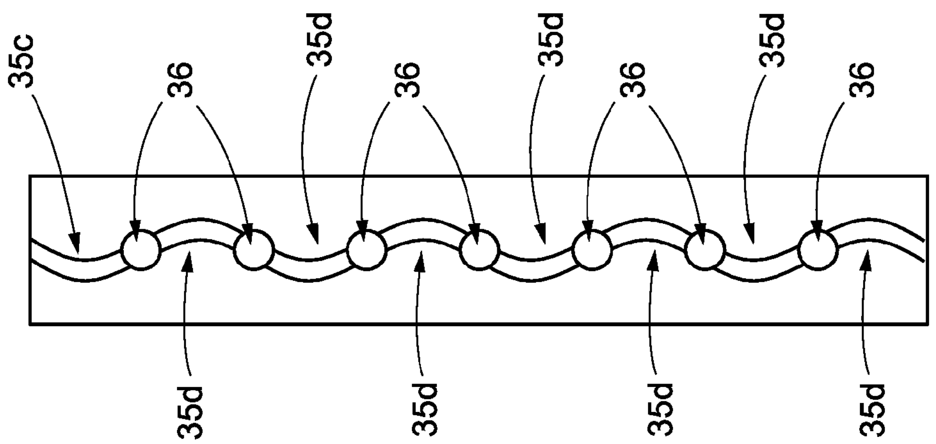

FIG. 6

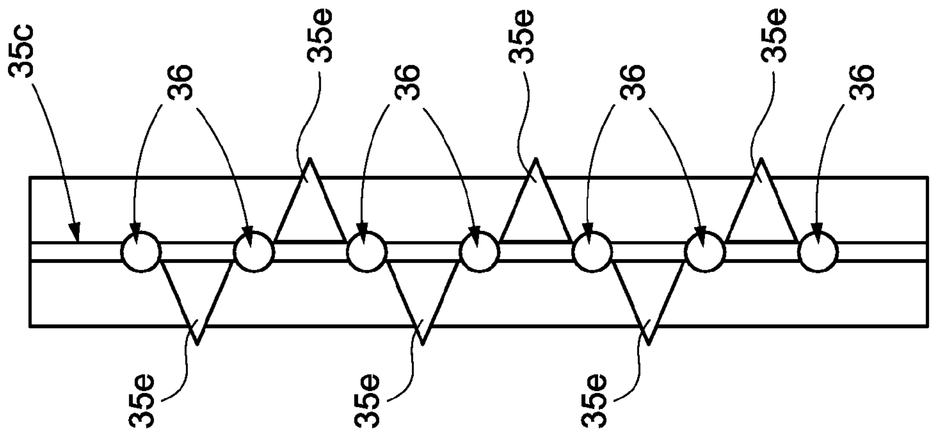

FIG. 7

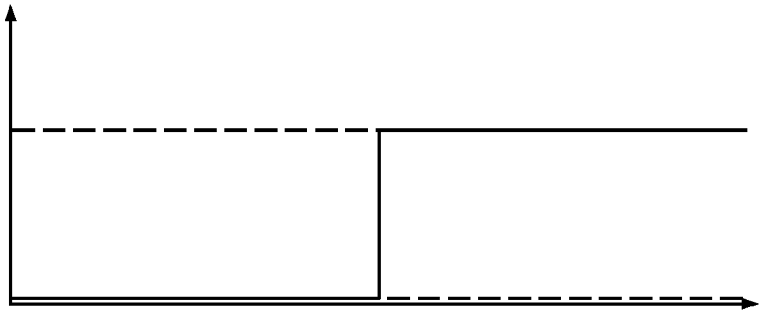

FIG. 8a

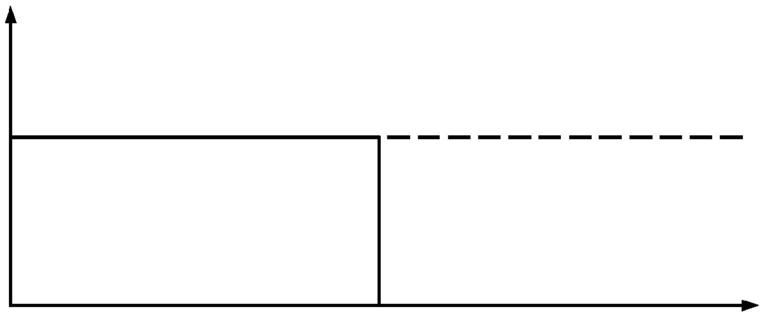

FIG. 8b

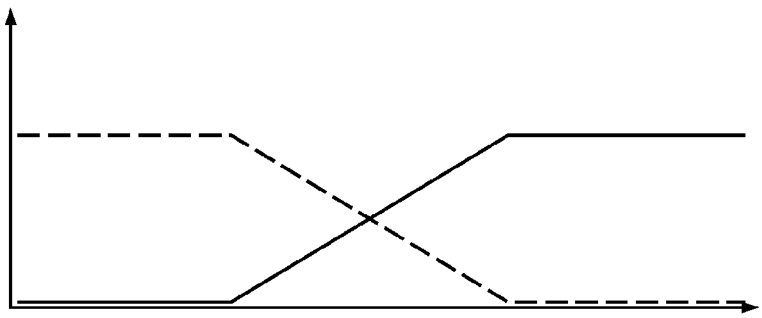

FIG. 9a

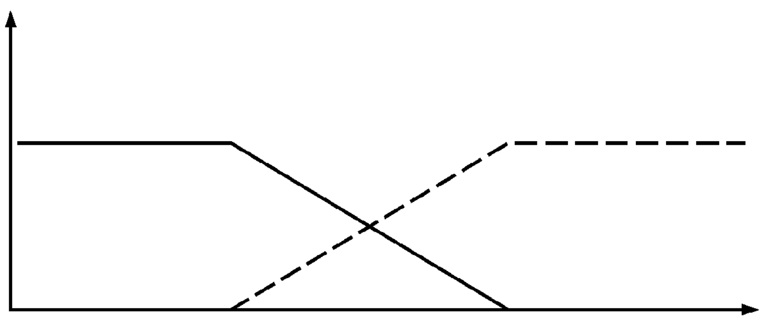

FIG. 9b

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European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 21 21 8284

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	US 2004/050057 A1 (BLAND ROBERT [US] ET AL) 18 March 2004 (2004-03-18) * paragraphs [0013], [0014]; figures * -----	1,13	INV. F23R3/28 F23R3/14 F23R3/36
X Y	US 2013/327046 A1 (BOBBA MOHAN KRISHNA [US] ET AL) 12 December 2013 (2013-12-12) * paragraphs [0014], [0017], [0018]; figures 2-4 * -----	1-3, 11-14 4,7-10	
X Y	US 2009/061365 A1 (PRADE BERND [DE]) 5 March 2009 (2009-03-05) * paragraph [0040]; figure 2 * -----	1,5,6, 11,12 7-10,15	
Y	EP 3 486 569 A1 (ANSALDO ENERGIA SWITZERLAND AG [CH]) 22 May 2019 (2019-05-22) * paragraph [0035]; figures * -----	4	
Y	WO 2014/114533 A1 (SIEMENS AG [DE]) 31 July 2014 (2014-07-31) * page 6, line 17 - page 8, line 11; figure 1 * -----	7-10,15	TECHNICAL FIELDS SEARCHED (IPC)
X	US 2019/086090 A1 (DOLMANSLEY TIMOTHY [GB] ET AL) 21 March 2019 (2019-03-21) * paragraph [0053] - paragraph [0069]; figures 2-5 * -----	1-3,11, 12	F23R

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	9 June 2022	Mootz, Frank

CATEGORY OF CITED DOCUMENTS

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