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(54) PREMIX BURNER FOR A GAS TURBINE ASSEMBLY FOR POWER PLANT SUITABLE TO BE FED WITH COMMON AND HIGHLY REACTIVE FUELS, METHOD FOR OPERATING THIS BURNER AND GAS TURBINE ASSEMBLY FOR POWER PLANT COMPRISING THIS BURNER

(57) A premix burner for a gas turbine assembly for a power plant, the premix burner (34) comprising: a swirler (35), having an upstream end fed by compressed air and a downstream end, the swirler being configured for swirling the air flow and being provided with premix injection nozzles (36) connected to a first gas fuel source; a casing (37) having a first end connected to the downstream end of the swirler (35) and a second end; a pilot lance (38) axially extending the swirler (35) and having a downstream end housed in the casing (37), the downstream end of the pilot lance (38) being provided with pilot injection nozzles connected to the first gas fuel source; a collar (39) having upstream end connected to second end of the casing (37) and a downstream end facing a combustion chamber. The collar (39) is provided with downstream injection nozzles (40) connected to a second gas fuel source; the second gas fuel source being a highly reactive H2-based fuel gas source.

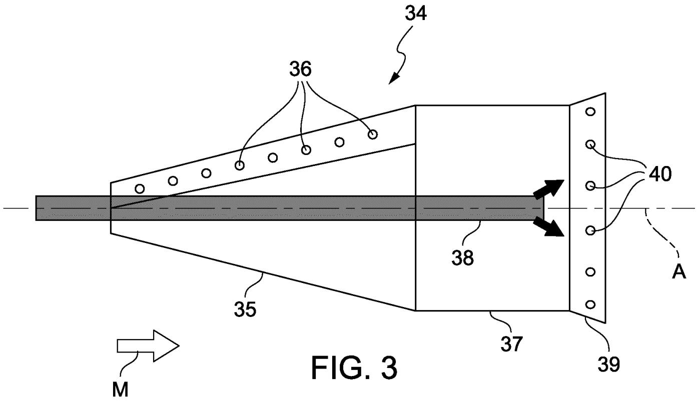

FIG. 3

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Description

Field of the Invention

[0001] The present invention relates to the technical field of the gas turbine assemblies for power plants (in the following only "gas turbine"). As known, in these assemblies an incoming air flow is compressed in a compressor and then mixed with fuel (gas fuel and/or oil fuel) in a combustor before entering in a turbine wherein the hot gas expansion generates a rotating work on a rotor in turn connected to a generator for power production. In particular, the present invention relates to all kinds of the above gas turbines (very general definition) wherein the combustor comprises at least a "premix burner". A premix burner is a burner configured not only for injecting the fuel in the compressed air flow but also for mixing (with a swirl) the compressed air and the fuel before injecting the mixture into the combustion chamber. In this context, the present invention refers to the problem of how to improve the premix burner in order to allow feeding not only with common fuels but also with highly reactive fuels, for instance fuel comprising H2.

Description of prior art

[0002] As known, in general a gas turbine assembly for power plants (in the following only gas turbine) comprises a rotor, a compressor, a combustor and a turbine unit. The compressor is configured for compressing air supplied at a compressor inlet. The compressed air leaving the compressor flows into the combustor provided with a plurality of burners configured for injecting fuel in the compressed air. The mixture of fuel and compressed air flows into a combustion chamber where this mixture is combusted for generating a hot gas flow. The expansion of this hot gas flow inside the turbine generates a rotating work on the rotor in turn connected to a generator. As known, the turbine and the compressor comprise a plurality of stages, or rows, of rotor blades that are interposed by a plurality of stages, or rows, of vanes supported by an outer casing surrounding the assembly.

[0003] In order to achieve a high efficiency, a high turbine inlet temperature is required. However, in general this high temperature involves an undesired high NOx emission level. In order to reduce this emission and to increase operational flexibility without decreasing the efficiency, a so called "sequential" gas turbine is particularly suitable. In general, a sequential gas turbine comprises two combustors or combustion stages in series wherein each combustor is provided with a plurality of burners and with at least a combustion chamber. Usually, the upstream or first combustor comprises a plurality of so-called "premix burners".

[0004] In general a premix burner is a burner configured not only for injecting the fuel in the compressed air but also for mixing with a swirl the compressed air and the fuel before injecting the mixture into the combustion chamber. This swirling mixture is obtained by providing a swirling cone configured for generating a swirl in the air flow wherein this cone is provided with a plurality of fuel injecting nozzles (called premix nozzles). This swirling mixture allows to reduce the NOx emission but the generated flame is not sufficiently stable under some conditions. In order to solve this problem of the premix flame stability, in the middle of the cone the burner is also provided with a pilot lance configured for injecting fuel in a more concentrate manner into a non-swirling air flow. The diffusion flame generated by the pilot is actually more stable but it generates higher NOx emission. In general, a premix burner is thus widely used because it allows to selective use a premix flame with low NOx emission during the normal operation and a more stable diffusion flame only under some conditions, for instance during the cold starting operation. Please notice that the present invention is not limited only to sequential gas turbines but it could be applied in all gas turbine provided with a premix burner as above described.

[0005] Starting from the above mentioned structure of a premix burner, today is present the need of improving the fuel flexibility while keeping low emission and high performance. In particular, a real challenge today is to use a highly reactive fuel, e.g. with high amounts of H2 or higher hydrocarbons (e.g. ethane, propane). Indeed, the increasing use of renewables for energy production is also accompanied by an increasing need for flexible power production, while aiming at carbon free emissions. The potential solutions of energy storage of excess generation from renewables through hydrogen production and precombustion carbon capture are gaining momentum. Thus, these scenarios require gas turbines capable of operation with hydrogen-based fuels. At the same time, the composition of natural gas considered for use within gas turbines is becoming significantly more variable due to increased use of liquefied natural gas and a wider range of gas sources and extraction methods. Fuel flexibility, both in terms of the amount of hydrogen and higher hydrocarbons is therefore of utmost importance in modern gas turbine development.

[0006] A change in fuel reactivity implies a change in flame location and behavior. In particular, higher fuel reactivity (like H2) forces the flame to move upstream, increasing NOx emissions, and potentially overheating the nozzles. Consequently, when burning highly reactive fuels (e.g. fuels containing large quantities of either higher hydrocarbons or hydrogen, including syngas and pure hydrogen) the flame, in particular the premix flame, moves upstream compared to the case of natural gas, thus increasing the risk of flashback. A solution for avoiding this flashback of the premix flame could be to lower the flame temperature (by feeding less fuel). However, the flame temperature cannot be lowered beyond a certain limit, called "lean blow out" temperature, because under this temperature the operation of the combustor is compromised. Thus, today the solution offered by the prior art practice in case of using highly reacting fuels is to switch the feeding from the premix nozzles to the pilot also during the normal operation. However, this solution cannot be accepted as a best practice because the pilot generates high NOx emissions and therefore a large amounts of diluents (nitrogen, steam) need to be added in the gas flow and/or selective catalytic reduction devices have to be used to keep the NOx emissions below the limits.

Disclosure of the invention

[0007] Accordingly, a primary object of the present invention is to provide a premix burner for a gas turbine assembly for power plants) and a method for operating this burner for overcoming the drawbacks of the current prior art practice. In particular, the scope of the present invention is to provide a premix burner configured to be selectively fed by common (natural) gas fuels and by highly reactive gas fuel, for instance H2-based fuel having a high % of H2 (in vol. up to 100%).

[0008] Thus, the present invention refers to a new and inventive premix burner for a gas turbine assembly for a power plant. The invention is not limited to a particular kind of gas turbine assembly but it can be applied to a general gas turbine comprising:

- a compressor for generating a compressed air flow;
- a combustor for adding fuel to the compressed air and generating a hot gas flow;
- a turbine driven by the hot gas flow.

[0009] Therefore, the gas turbine may involve a single combustion stage or a double/sequential combustion. The following detailed description will refer to two not limiting example of sequential combustion gas turbines.

[0010] A first feature of the present invention is to provide a first gas fuel source and a second gas fuel source wherein the first source delivers natural gas fuel and the second source delivers H2-based gas fuel. Indeed, the scope of the present invention is, as foregoing cited, to provide a premix burner configured to be selectively fed by common (natural) gas fuels and by highly reactive gas fuel. Please notice that the source may be proximal or distal with respect to the burner and each source may comprise more than one feeding lines for feeding with the same fuel a plurality of components of the gas turbine.

[0011] A premix burner suitable to be improved by the present invention is defined in the preamble of claim 1. In general, this premix burner is a premix burner comprising:

- a swirler (preferably an axial swirler) having an upstream end fed by compressed air and a downstream end; as known the swirler is configured for swirling the air flow and it is provided with premix injection nozzles connected to a first gas fuel source;
- a casing having a first end connected to the downstream end of the swirler and a second end;
- a pilot lance axially extending along the swirler and having a downstream end housed in the casing; as known the downstream end of the pilot lance is provided with pilot injection nozzles connected to the first gas fuel source.

[0012] Preferably, the swirler comprises a cone body, the casing comprises a tubular body.

[0013] During normal operation, mainly only the premix injection nozzles are fed by the fuel gas because a premixed flame generates less NOx emissions. However, under certain circumstances, the premixed flame is not stable enough. For improving flame stability the gas flow or part of it is directed to the pilot generating a more stable flame that, however, generates higher Nox emissions. In case of H2-based gas fuel the feeding of the premix injection nozzles may generate drawbacks because the flame is too reactive and a flashback effect may occur.

[0014] The premix burner of the present invention comprises a collar having an upstream end connected to the second end of the casing and a downstream end facing a combustion chamber. As the main feature of the invention the collar is provided with downstream injection nozzles connected to a second gas fuel source.

[0015] Thus, in case of the second gas fuel source is a source feeding H2-based gas fuel or in general highly reactive fuel, this fuel is not (or only in minimal part) fed to premix nozzles (flashback problem), is not (or only in minimal part) fed to the pilot nozzles (Nox problem) but it is mainly fed to the downstream injection nozzles that involve a kind of compromise between a diffusion and a premixed flame with an acceptable Nox emissions without any flashback risk.

[0016] The above solution therefore allows to overcome the prior art problem foregoing stated. However, in general the present invention and the new third stage of injection obtained by the new downstream injection nozzles allows to realize a more flexible burner. Indeed, the premix injection nozzles and the pilot injection nozzles may be also connected to the second gas fuel source as also the downstream injection nozzles may be connected to the first gas fuel source so that the gas fuels may be fed to all nozzles depending on the fuel compositions and engine load of the system.

[0017] According to an example, the downstream injection nozzles are annular arranged about the burner axis A, i.e. in a plane orthogonal to the burner (pilot) axis A.

[0018] According to a second example, the downstream injection nozzles are arranged along a circumference (in a plane) inclined with respect to the burner axis A. In general, the downstream injection nozzles may disclose different axial positions.

[0019] Preferably, each nozzle of the downstream injection nozzles is configured for generating an injected flow inclined with respect to the burner axis A, i.e. not an axial flow.

[0020] Preferably, each nozzle of the downstream injection nozzles is a coaxial nozzle comprising an inner nozzle fed by the highly reactive H2-based fuel gas and an outer nozzle fed by compressed air.

[0021] Preferably, the collar is provided with additional air nozzles fed by compressed air.

[0022] Preferably, the above air nozzles are configured for generating an axial air flow.

[0023] As evident from the above description, the invention refers also to a method for operating such a premix burner; the method comprising the steps of:

a) providing a premix burner as described;
b) feeding the premix injection nozzles and/or the pilot injection nozzles with gas fuel coming from the first fuel source whereas the feeding of the downstream injection nozzles is not operated;
c) decreasing the feeding of the premix injection nozzles and/or the pilot injection nozzles and starting with the feeding of the downstream injection nozzles with H2-based fuel coming from the second fuel source.

[0024] Of course, the method may comprise also the step of:
d) decreasing the feeding of the downstream injection nozzles and re-starting with the feeding of the premix injection nozzles and/or the pilot injection nozzles.

[0025] The decreasing and starting phases in steps c) and/or d) may be performed simultaneously or a double feeding may be temporarily performed. Of course, the step of "decreasing" the feeding depends on the gas fuel composition and on the engine load of the system.

[0026] In general, the method allows to feed the premix injection nozzles and/or pilot injection nozzles and/or the downstream injection nozzles with the natural gas fuel or the H2-based gas fuel in different rate depending on the fuel composition and on the engine load of the system.

[0027] It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the invention as claimed. Other advantages and features of the invention will be apparent from the following description, drawings and claims.

[0028] The features of the invention believed to be novel are claimed in the appended claims.

List of drawings

[0029] Further benefits and advantages of the present invention will become apparent after a careful reading of the detailed description with appropriate reference to the accompanying drawings.

[0030] The invention itself, however, may be best understood by reference to the following detailed description of the invention, which describes an exemplary embodiment of the invention, taken in conjunction with the accompanying drawings, in which:

- figure 1 is a first example of a gas turbine that can be provided with a premix burner according to the invention;
- figure 2 is a second example of a gas turbine that can be provided with a premix burner according to the invention;
- figure 3 is a first example of a premix burner according to the invention;
- figure 4 is a second example of a premix burner according to the invention;
- figure 5 a first example of a downstream nozzle according to the invention.

Detailed description

[0031] In cooperation with attached drawings, the technical contents and detailed description of the present invention are described thereinafter according to preferred embodiments, not being used to limit its executing scope. Any equivalent variation and modification made according to appended claims is all covered by the claims claimed by the present invention.

[0032] Reference will now be made to the drawing figures to describe the present invention in detail.

[0033] Reference is now made to Fig. 1 that is a schematic view of a first example of a gas turbine 1 comprising a sequential combustor that can be operated according to the method of the present invention. In particular, figure 1 discloses a gas turbine with a high pressure and a low pressure turbine. Following the main gas flow 2, the gas turbine 1 of figure 1 comprises a compressor 3, a first combustor 31, a high-pressure turbine 5, a second combustor 32 and a low-pressure turbine 7. The compressor 3 and the two turbines 5, 7 are part of or are connected to a common rotor 8 rotating around an axis 9 and surrounded by a concentric casing 10. The compressor 3 is supplied with air and is provided with rotating blades 18 and stator vanes 19 configured for compressing the air entering the compressor 3. On leaving the compressor, the compressed air flows into a plenum 11 and from there into a plurality of first burners 12 of the first combustor 31 arranged as a ring around the axis 9. Each first burner 12 is configured for injecting fuel (supplied by a first fuel supply 13) in the air flow, in particular this first burner 12 may be defined as a "premix" burner because it is configured for mixing the air and the injected fuel before the ignition point. Figures 4 and 5 (that will be described in the following) disclose an example of a premix burner according to the present invention. The fuel/compressed air mixture flows into a first combustion chamber 4 annularly shaped where this mixture is combusted via a forced ignition, for instance by a spark igniter. The resulting hot gas leaves the first combustor chamber 4 and is partially expanded in the high-pressure turbine 5 performing work on the rotor 8. Downstream of the high-pressure turbine 5 the hot gas partially expanded flows into a second burner 33 where fuel supplied by a fuel lance 14 is injected. The partially expanded gas has a high temperature and contains sufficient oxygen for further combustion that occurs based on a self-ignition in the second combustion chamber 6 arranged downstream of the second burner 33. This second burner 33 is also called a "reheat" burner. The reheated hot gas leaves the second combustion chamber 6 and flows in the low-pressure turbine 7 where it is expanded performing work on the rotor 8. The low-pressure turbine 7 comprises a plurality of stages, or rows, of rotor blades 15 arranged in series in the main flow direction. Such stages of blades 15 are interposed by stages of stator vanes 16. The rotor blades 15 are connected to the rotor 8 whereas the stator vanes 16 are connected to a vane carrier 17 that is a concentric casing surrounding the low-pressure turbine 7.

[0034] Reference is now made to Fig. 2 that is a schematic view of a second example of a gas turbine 20 comprising a sequential combustor that can be operated according to the method of the present invention. In particular, figure 2 discloses a gas turbine 20 provided with a compressor 29, one turbine 21 and a sequential combustor 22. The sequential combustor 22 of figure 2 comprises a plurality of so-called can combustors, i.e. a plurality of cylindrical casings wherein each can combustor houses a plurality of first burners 24, for instance four first burners 24, a first combustion chamber 25, a second burner 26, and a second combustion chamber 27. Upstream the second burner 26 an air mixer (not represented) may be provided configured for adding air in the hot gas leaving the first combustion chamber 25. The sequential combustor arrangement is at least in part housed in an outer casing 28 supporting the plurality of can combustor 22 arranged as a ring around the turbine axis. A first fuel is introduced via a first fuel injector (not shown) into the first burners 24 wherein the fuel is mixed with the compressed gas supplied by the compressor 29. Also each first burner 24 of this embodiment is a "premix" burner configured for generating a premix flame and a diffusion flame. Each first burner 24 of figure 2 and each first burner 12 of figure 1 is independently operable, i.e. each first burner may be switched off independently of the other first burners and each first burner may be operated independently in terms of ratio between the fuel injected in the diffusion mode and the fuel injected in the premix mode. Finally, the hot gas leaving the second combustion chamber 27 expands in the turbine 21 performing work on a rotor 30.

[0035] Reference is now made to figure 3 that is a first example of a premix burner according to the invention. According to this example the premix burner 34 comprises:

- a cone body 35 having an upstream end fed by compressed air M and an enlarged downstream end; wherein the cone body (as known) is configured for swirling the air flow and it is provided with premix injection nozzles 36 connected to a first gas fuel (natural gas fuel) source;
- a tubular body 37 having a first end connected to the downstream end of the cone body 35 and a second end towards the combustion chamber;
- a pilot lance 38 axially extending in the middle of the burner and having a downstream end housed in the tubular body 37, in this example the pilot lances ends before the second end of the tubular body 37. As known, the downstream end of the pilot lance is provided with pilot injection nozzles connected to the same first gas fuel source feeding the premix nozzles;
- a collar body 39 having an upstream end connected to second end of the tubular body 37 and a downstream end facing the combustion chamber.

[0036] The above structure is well known by the skilled person and thus no additional detail is due for a clear understanding of the context of the invention.

[0037] As disclosed in figure 3, the collar body 39 is provided with downstream injection nozzles that are connected to a second gas fuel source. This fuel source is a highly reactive H2-based fuel gas source so that the downstream injection nozzles are fed by this particular kind of fuel. In this example, the downstream injection nozzles are annularly arranged about the burner axis A, i.e. along a circle in a plane orthogonal to the burner axis.

[0038] Please notice that the burner may be provided without the collar. In this case the downstream injection nozzles are arranged at the downstream end of the tubular body.

[0039] Figure 4 discloses a second example of a premix burner according to the invention. According to this example, quite similar to the previous one, the downstream injection nozzles are arranged along a circumference in a plane not orthogonal but inclined with respect to the burner axis (A). Of course also additional different dispositions are falling in the scope of protection of the present application.

[0040] Finally, figure 5 discloses a first example of a downstream nozzle according to the invention. According to this example, each nozzle of the downstream injection nozzles is configured for generating an injected flow inclined with respect to the burner axis A. the nozzle is a coaxial nozzle comprising an inner nozzle fed by the highly reactive H2-based fuel gas and an outer nozzle fed by compressed air. Moreover, beside the downstream injection nozzles, the collar body is provided with additional air nozzles fed by compressed air wherein each of these the air nozzles 41 is configured for generating an axial air flow.

[0041] Although the invention has been explained in relation to its preferred embodiment(s) 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 present invention. It is, therefore, contemplated that the appended claim or claims will cover such modifications and variations that fall within the true scope of the invention.

Claims

1. A premix burner for a gas turbine assembly for a power plant, the premix burner (34) comprising:

   - a swirler (35), having an upstream end fed by compressed air and a downstream end, the swirler being configured for swirling the air flow and being provided with premix injection nozzles (36) connected to a first gas fuel source;
   - a casing (37) having a first end connected to the downstream end of the swirler (35) and a second end;
   - a pilot lance (38) axially extending the swirler (35) and having a downstream end housed in the casing (37), the downstream end of the pilot lance (38) being provided with pilot injection nozzles connected to the first gas fuel source;
   - a collar (39) having upstream end connected to second end of the casing (37) and a downstream end facing a combustion chamber;

   characterized in that
   the collar (39) is provided with downstream injection nozzles (40) connected to a second gas fuel source; the second gas fuel source being a highly reactive H2-based fuel gas source.

2. The premix burner according to claim 1, wherein the swirler (35) comprises a cone body and/or the casing comprises a tubular body and/or the collar (39) is integral with the casing (37).

3. The premix burner according to any one of the foregoing claims, wherein the premix injection nozzles (36) and the pilot injection nozzles are also connected to the second gas fuel source; the downstream injection nozzles (40) are also connected to the first gas fuel source so that the gas fuels may be fed to all nozzles with corresponding rates depending on the fuel compositions and engine load of the system.

4. The premix burner according to any one of the foregoing claims, wherein the downstream injection nozzles (40) are annular arranged about the burner axis (A).

5. The premix burner according to any one of the foregoing claims 1-3, wherein the downstream injection nozzles (40) are arranged at varying axial locations

6. The premix burner according to any one of the foregoing claims, wherein each nozzle of the downstream injection nozzles (40) is configured for generating an injected flow inclined with respect to the burner axis (A).

7. The premix burner according to any one of the foregoing claims, wherein each nozzle of the downstream injection nozzles (40) is a coaxial nozzle comprising an inner nozzle fed by fuel gas and an outer nozzle fed by compressed air.

8. The premix burner according to any one of the foregoing claims, wherein collar (39) is provided with additional air nozzles (41) fed by compressed air.

9. The premix burner according to claim 8, wherein the air nozzles (41) are configured for generating an axial air flow.

10. A method for operating a premix burner for a gas turbine assembly for a power plant; the method comprising the steps of:

    a) providing a premix burner according to any one of the foregoing claims from 1 to 9;
    b) feeding the premix injection nozzles and/or the pilot injection nozzles with fuel coming from the first fuel source whereas the feeding of the downstream injection nozzles is not operated;
    c) decreasing the feeding of the premix injection nozzles and/or the pilot injection nozzles and starting with the feeding of the downstream injection nozzles.

11. Method as claimed in claim 10, wherein the method comprises the step of:
    d) decreasing the feeding of the downstream injection nozzles and re-starting or increasing with the feeding of the premix injection nozzles and/or the pilot injection nozzles.

12. Method as claimed in claim 10 or 11, wherein the stopping and starting phases in steps c) and/or d) are performed simultaneously or a double feeding may be temporary performed.

13. A gas turbine for a power plant, the gas turbine comprising:

    - a compressor for generating a compressed air flow;
    - a combustor for adding fuel the compressed air and generating a hot gas flow;
    - a turbine driven by the hot gas flow;
    - a first gas fuel source;
    - a second gas fuel source;

    wherein the combustor comprises at least a premix burner according to any one of the foregoing claims from 1 to 9.

14. The gas turbine according to claim 13, wherein the gas combustor is a sequential combustor (22), the sequential combustor (22) comprising:

- a first combustor provided with a plurality of premix burners (12, 24);
- a second combustor provided with a plurality of second burners (26, 33), fed by hot gas leaving the first combustor.

15. The gas turbine as claimed in claim 14, wherein the first and the second combustor are annular shaped and divided by a stage of turbine.

16. The gas turbine as claimed in claim 14, wherein the sequential combustor comprises a plurality of can combustors, each can combustor comprising the first and the second combustor divided by a dilution air mixer.

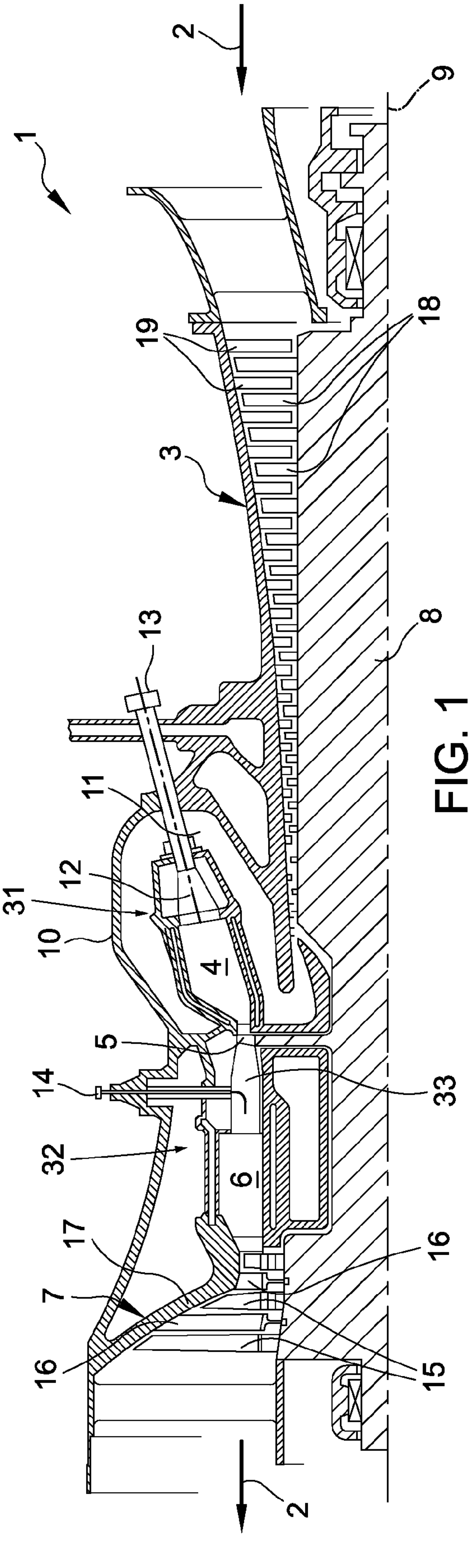
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FIG. 1

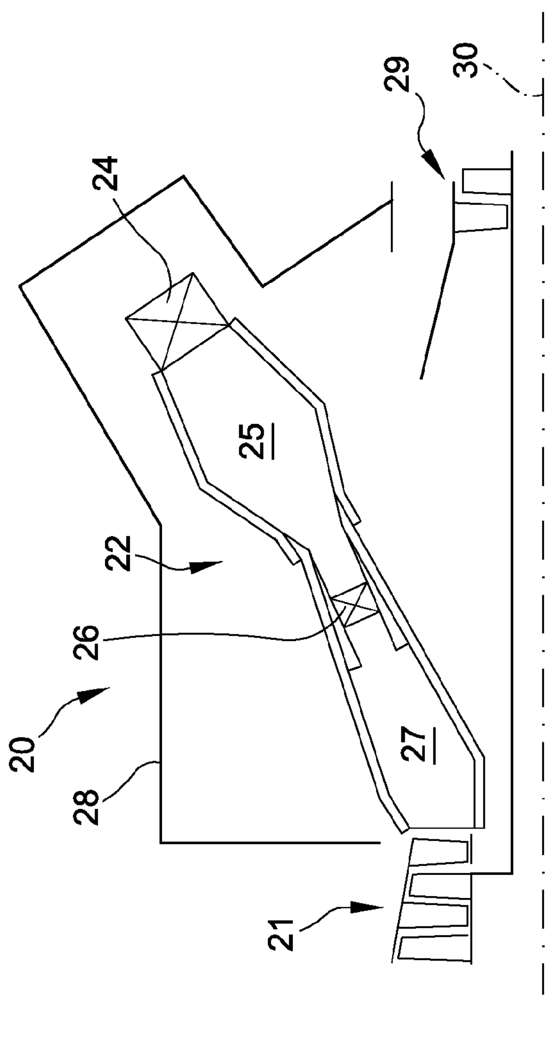
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FIG. 2

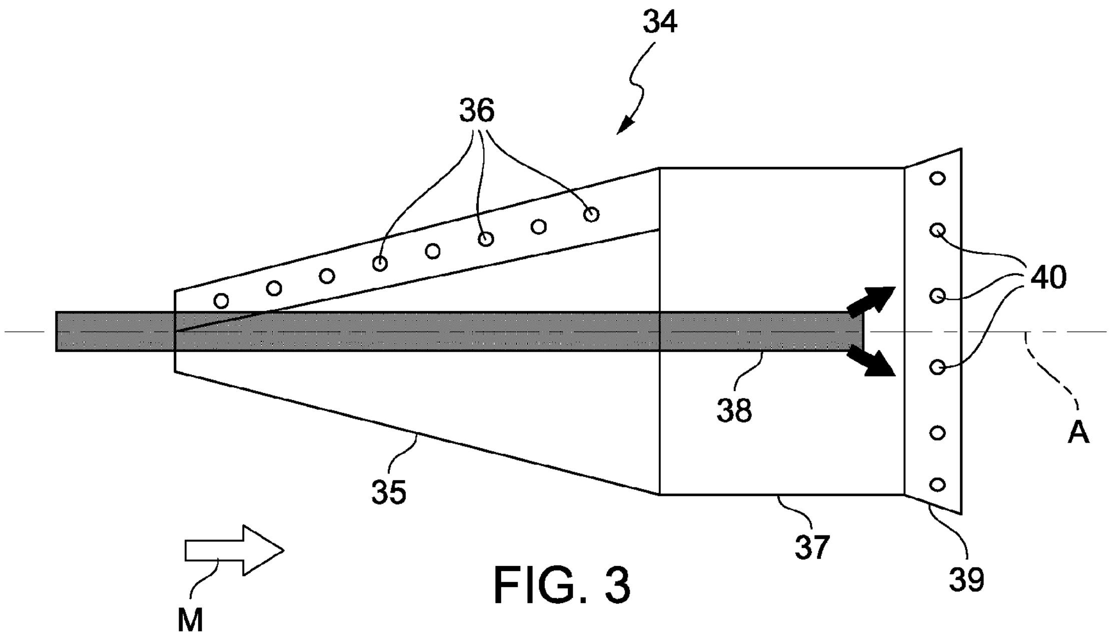

FIG. 3

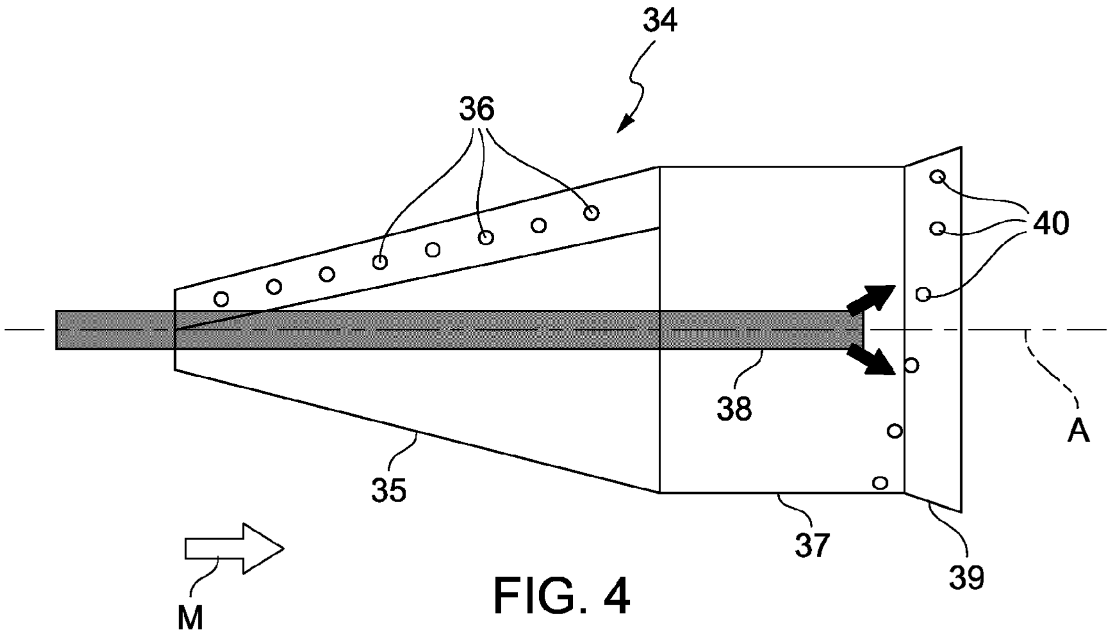

FIG. 4

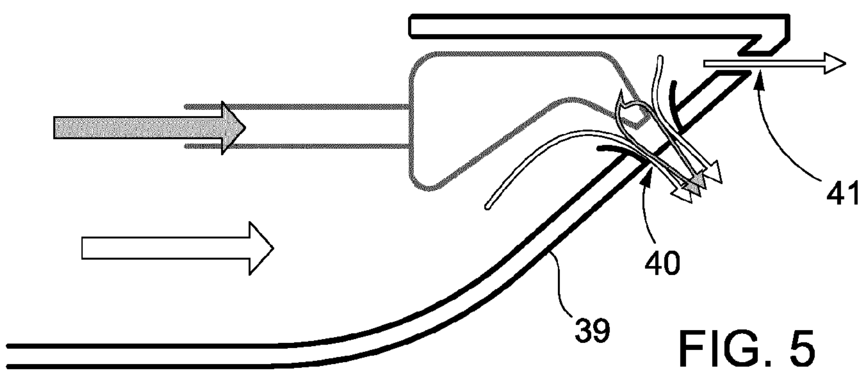

FIG. 5

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 21 21 6659

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	US 2018/216828 A1 (JOHANSSON NICKLAS [SE] ET AL) 2 August 2018 (2018-08-02) * paragraphs [0030], [0041], [0047] - paragraphs [0052], [0055], [0056]; figure 1 *	1,2,4,6,13 3,7-9	INV. F23R3/46 F23R3/28 F23R3/14 F23R3/34 F23R3/36
Y A	US 2019/162414 A1 (OGATA MASAHIRO [JP] ET AL) 30 May 2019 (2019-05-30) * paragraph [0040] - paragraph [0049]; figure 2 *	3 1	
Y	US 2009/081599 A1 (BERNERO STEFANO [CH] ET AL) 26 March 2009 (2009-03-26) * paragraph [0039] - paragraph [0042]; figure 2 *	7-9	
X	US 2004/226297 A1 (GRIFFIN TIMOTHY [CH] ET AL) 18 November 2004 (2004-11-18) * paragraph [0034] - paragraph [0036]; figure 2 * * paragraph [0047]; figure 7 *	1,2,4,6,8,13	TECHNICAL FIELDS SEARCHED (IPC)
X	US 2012/047907 A1 (ZAJADATZ MARTIN [DE] ET AL) 1 March 2012 (2012-03-01) * paragraph [0018] - paragraphs [0035], [0041], [0042]; figures 1,3 *	1,2,4,10,13,16	F23R F23C F23D
X	US 6 210 152 B1 (HAFFNER KEN [CH] ET AL) 3 April 2001 (2001-04-03) * column 4, line 57 - column 5, line 20; figure 4 * * column 6, line 1 - line 59; figure 6 *	1,2,4,6,7,13	
X	US 2013/224672 A1 (CARRONI RICHARD [CH] ET AL) 29 August 2013 (2013-08-29) * paragraphs [0020], [0021]; figure 1 * * paragraphs [0029], [0030]; figure 4 *	1-4,6,13-15	

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	3 June 2022	Mootz, Frank

CATEGORY OF CITED DOCUMENTS

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