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(54) SECOND-STAGE COMBUSTOR FOR A SEQUENTIAL COMBUSTOR OF A GAS TURBINE

(57) A combustor of a gas turbine, including: a first-stage combustor and a second-stage combustor (13), arranged downstream of the first-stage combustor and including a second-stage combustion chamber (20) extending along an axial direction; an axial lance injector (16); and a flame stabilizer device (23). The axial lance injector (16) includes an elongated streamlined body (30) extending in the axial direction from the first-stage combustor into the second-stage combustion chamber (20) through a transition region (28) of the second-stage combustor (13). The elongated streamlined body (30) and the transition region (28) prevent gas recirculation in the transition region (28). First cross-flow injection nozzles (32) and second cross-flow injection nozzles (33) are provided on the elongated streamlined body (30) at respective axial locations and the flame stabilizer device (23) is arranged downstream of the first cross-flow injection nozzles (32) and of the second cross-flow injection nozzles (33).

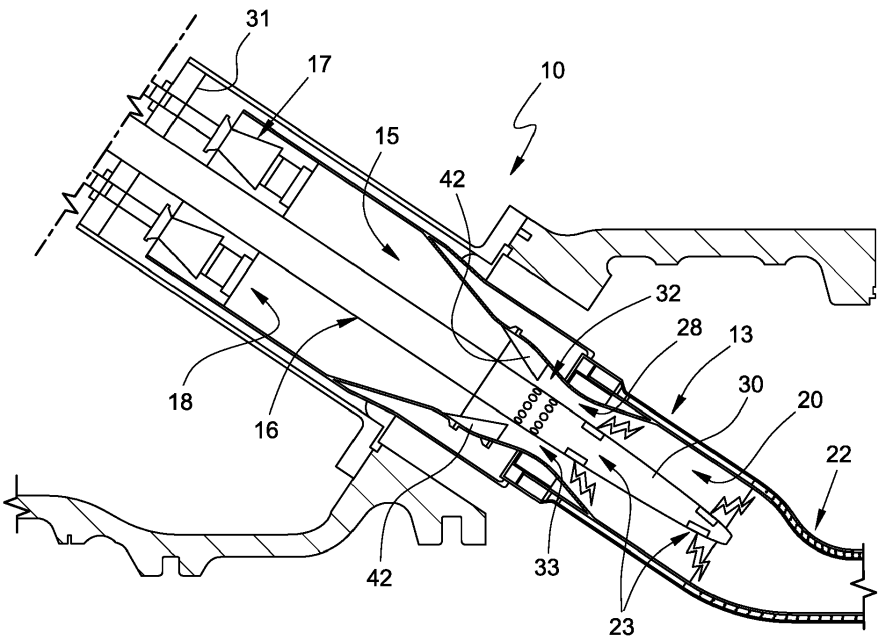

FIG. 2

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Description

TECHNICAL FIELD

[0001] The present invention relates to a second-stage combustor for a sequential combustor of a gas turbine..

BACKGROUND

[0002] As it is known, increase of power output and efficiency of gas turbines for power plants involves several challenges and fuel injection to obtain efficient and emission-compliant combustion is among the most critical ones. In order to achieve higher power output, in fact, also fuel supply is to be significantly increased and injection must be carried out in such a manner that the fuel flowrate is adequately mixed with a flowrate of a dilutant fluid (e.g. fresh air or exhaust of first combustor stage in sequential combustors). Poor mixing may negatively affect combustion and levels of pollutant emissions.

[0003] The need to supply increased fuel flowrates and to provide adequate mixing led to developing burners with complex structures. Known burners tend to meet heavy requirements in terms of fuel supply and mixing capacity, nevertheless some limitations still stand, in particular because complex structure has important implications. Depending on the type of combustor, multipoint lance injectors or streamlined bodies with critical aerodynamic properties need to be provided. Manufacturing of such complex structures may be difficult and processes required to obtain acceptable results may involve substantial cost.

[0004] Moreover, it is in general desired that burner assemblies (i.e. devices devoted to fuel injection and mixing) can be retracted form their housings for the purpose of maintenance or retrofitting without the need to disassemble large part of the combustors. In particular, it is desired that burner assemblies are axially retractable for simple extraction from can combustors. Exactly on account of their complex structure, however, known burner assemblies cannot be retracted.

SUMMARY OF THE INVENTION

[0005] It is an aim of the present invention to provide a second-stage combustor for a sequential combustor of a gas turbine and a method of controlling a sequential combustor of gas turbine with a first-stage combustor and a second-stage combustor, which allow to overcome or at least to attenuate the limitations described.

[0006] According to the present invention, there is provided a combustor of a gas turbine, comprising:

a first-stage combustor and a second-stage combustor, wherein the second-stage combustor is arranged downstream of the first-stage combustor and includes a second-stage combustion chamber extending along an axial direction;

an axial lance injector; and

a flame stabilizer device;

wherein the axial lance injector comprises:

an elongated streamlined body extending in the axial direction from the first-stage combustor into the second-stage combustion chamber through a transition region of the second-stage combustor, wherein the elongated streamlined body and the transition region are configured to prevent gas flowing from the first-stage combustor to the second-stage combustion chamber from recirculating in the transition region;

a plurality of first cross-flow injection nozzles and a plurality of second cross-flow injection nozzles provided on the elongated streamlined body at respective axial locations;

and wherein the flame stabilizer device is arranged downstream of the first cross-flow injection nozzles and of the second cross-flow injection nozzles.

[0007] The combustor combines an axial lance injector with extremely simple design and a flame stabilizer device that allows to anchor the flame at one or more desired locations. In particular, the front flame may be set at an axially downstream location at full load, to reduce post-flame residence time and production of NOx.

[0008] The axial lance injector is essentially defined by an elongated streamlined body that extends from the first-stage combustor into the second-stage combustion chamber and exploits cross-flow injection for providing effective supply and mixing even when large fuel flowrates are required. Cross-flow injection nozzles may be provided on the surface of the elongated streamlined body and there is no need for special components, creating complex fluid-dynamic structures. As a result, the axial lance injector may be manufactured by conventional manufacturing processes and it is not necessary to resort to additive techniques, to the advantage of cost. In addition, the axial lance injector is easily retractable in the axial direction, thus simplifying maintenance and retrofitting operations.

[0009] Axial locations of the first and second cross-flow injection nozzles can be selected to exploit different time delays from injection locations and the flame front. This can be used for the purpose of mitigating thermoacoustic oscillations and for providing short mixing paths for highly reactive fuels.

[0010] According to an aspect of the present invention, the second cross-flow injection nozzles are axially displaced downstream of the first cross-flow injection nozzles.

[0011] According to an aspect of the present invention, the first cross-flow injection nozzles are fluidly coupled to a fuel gas supply line and the second cross-flow injection nozzles are fluidly coupled to a liquid fuel supply line.

[0012] Separate supply paths for different fuels may be provided. Advantages of separate oil injection may thus be exploited. In particular, less strict purging requirements are allowed. Also, separate supply valves can be used and mixing paths can be separately optimized for different fuels.

[0013] According to an aspect of the present invention, at least one of the first cross-flow injection nozzles is axially displaced with respect to the other first cross-flow injection nozzles.

[0014] According to an aspect of the present invention, the first cross-flow injection nozzles are staggered in the axial direction.

[0015] According to an aspect of the present invention, at least one of the second cross-flow injection nozzles is axially displaced with respect to the other second cross-flow injection nozzles.

[0016] According to an aspect of the present invention, the second cross-flow injection nozzles are staggered in the axial direction.

[0017] All the above features, separately and possibly in combination, allow to optimize beneficial effects of fuel injection at different axial locations, in particular with respect to mixing paths, ignition time and damping of thermoacoustic oscillations.

[0018] According to an aspect of the present invention, the second cross-flow injection nozzles are oriented at such an angle that fuel oil is injected in the second-stage combustion chamber with a non-zero axial component of velocity.

[0019] Inclination of the second cross-flow injection nozzles allows to reduce residence time of highly reactive fuel oil, because injected fuel leaves the nozzles with a non-zero axial component of velocity. In turn, lower residence time reduces the need for mixing additional water to fuel oil. In some cases, additional water may not be required at all, especially when inclination of the second cross-flow injection nozzles is supplemented by advanced flame location, as permitted by the flame stabilizer device.

[0020] According to an aspect of the present invention, the combustor comprises vortex generators upstream of the second-stage combustion chamber.

[0021] Large vortex generators determine relatively slow mixing, i.e. longer distance and time are required. At full load, however, the flame stabilizer device may be used to set the flame location downstream. So, despite the large fuel flow rate at full load, efficient mixing is achieved. Early self-ignition of the air and fuel mixture is in any case avoided. The vortex generators may have quite simple shape (e.g. prismatic) and manufacturing thereof does not entail substantial problems in relation to both process complexity and cost.

[0022] According to an aspect of the present invention, the flame stabilizer device comprises a full-load flame stabilizer at a downstream end of the elongated streamlined body.

[0023] Stabilizing the full-load flame at a downstream location helps to enhance beneficial effects in terms of increased mixing distance and reduce post-flame residence time, especially at full-load. This is particularly beneficial for the purpose of maintaining low NOx emission at full-load.

[0024] According to an aspect of the present invention, the flame stabilizer device comprises at least one partial-load flame stabilizer between the second cross-flow injection nozzles and the full-load flame stabilizer.

[0025] Flame location may be adjusted during operation in accordance with load requirement. At partial load, flame temperature is low and long post-flame residence time is desired to achieve complete oxidation of carbon contained in the fuel flow and to reduce CO emissions. Thus, it may be of advantage to set the flame location at an upstream position. On the other hand, at full-load it is preferred to have the flame located as downstream as possible in the second-stage combustion chamber, to obtain good air-fuel mixing and reduce production of NOx.

[0026] According to an aspect of the present invention, the flame stabilizer device comprises at least one of:

a downstream electrode system, operable to provide ignition energy in the second-stage combustion chamber at least at one flame location; and
a change in cross section of the second-stage combustion chamber in the axial direction, the change in cross section being configured to cause gas flowing through the second-stage combustion chamber to recirculate at least at one flame location.

[0027] Flame location can be thus effectively and precisely controlled during operation of the gas turbine.

[0028] According to an aspect of the present invention, the first-stage combustor comprises an upstream end-cap and the elongated streamlined body is supported at the upstream end-cap.

[0029] In this manner, extraction of the axial lance injector is favoured and operations of maintenance and maintenance and retrofitting operations are simplified.

[0030] According to an aspect of the present invention, a flow channel is defined in the first-stage combustor and in the second-stage combustor around the elongated streamlined body and a cross section of the flow channel changes gradually along the flow direction in the transition region.

[0031] The smooth transition between the first-stage combustor and the second-stage combustor prevents flow stagnation at the inlet of the second-stage combustion chamber. In this manner, stable flame anchorage is prevented and the flame location may be moved downstream as desired during operation using the flame stabilizer device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] The present invention will now be described with reference to the accompanying drawings, which show some non-limitative embodiment thereof, in which:

- Figure 1 is simplified block diagram of a gas turbine assembly;
- Figure 2 is a longitudinal section through a sequential combustor including a second-stage combustor in accordance to an embodiment of the present invention;
- Figure 3 is an enlarged longitudinal section through the second-stage combustor of figure 2;
- Figure 4 is a perspective view of an enlarged detail of the second-stage combustor of figure 2;
- Figure 5 is a longitudinal section through a second-stage combustor in accordance to another embodiment of the present invention;
- Figure 6 is a side view an enlarged detail of the second-stage combustor of figure 5; and
- Figure 7 is a longitudinal section through a second-stage combustor in accordance to another embodiment of the present invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0033] Figure 1 shows a simplified view of a gas turbine assembly, designated as whole with numeral 1. The gas turbine assembly 1 comprises a compressor section 2, a combustor assembly 3 and a turbine section 5. The compressor section 2 and the turbine section 3 extend along a main axis A. An airflow compressed in the compressor section 2 is mixed with fuel and is burned in the combustor assembly 3, possibly added with dilution air. The burned mixture is then expanded to the turbine section 5 and converted in mechanical power.

[0034] A controller 7, which is configured to define a setpoint for the gas turbine, receives state signals from sensors 8 and operates the gas turbine through actuators 9 to provide a controlled power output.

[0035] The combustor assembly 3 is a two-stage sequential combustor and comprises a plurality of can combustors 10 arranged around the main axis A. Each of the can combustors 10, one of which is shown in Figure 2, comprises a first-stage combustor 12 and a second-stage combustor 13 sequentially arranged and defining a flow channel 15. An axial injector lance 16 extends from the first-stage combustor 12 into the second-stage combustor 13.

[0036] More specifically, the first-stage combustor 12 comprises a burner 17 and a first-stage combustion chamber 18.

[0037] The second-stage combustor 13, which is illustrated in greater detail in Figure 3, is arranged downstream of the first-stage combustor 12 and includes a second-stage combustion chamber 20 extending along an axial direction and a transition duct 22 for coupling to the turbine section 5, here not shown. Moreover, a flame stabilizer device 23 is provided in the second-stage combustor 13.

[0038] The second-stage combustion chamber 20 extends along an axial direction downstream of the first-stage combustor 12. In one embodiment, the second-stage combustion chamber 20 comprises an outer liner 24 and inner liner 25. The outer liner 24 surrounds the inner liner 25 at a distance therefrom, so that a cooling channel 27 is defined between the outer liner 24 and the inner liner 25. The inner liner 25 delimits the flow channel 15 outwards in the second-stage combustion chamber 20 and forms a transition region 28 that joins the first-stage combustor 12 in such a way to define a smooth transition without steps and possibly sharp edges.

[0039] The axial lance injector 16 comprises an elongated streamlined body 30 that extends in the axial direction from the first-stage combustor 12 into the second-stage combustion chamber 20 through the transition region 28 of the second-stage combustor 13. A downstream end of the elongated streamlined body 30 is arranged at an interface between the second-stage combustion chamber 20 and the transition duct 22. In one embodiment, the first-stage combustor 12 comprises an upstream end-cap 31 and the elongated streamlined body 30 is supported at the upstream end-cap 31 together with the burner 17 (see figure 2).

[0040] The elongated streamlined body 30 and the transition region 28 are configured to prevent gas flowing from the first-stage combustor 12 to the second-stage combustion chamber 20 from recirculating in the transition region 24. In one embodiment, for example, the elongated streamlined body 30 has a smooth ellipsoidal surface tapering towards a downstream end 30a. The surface of the elongated streamlined body 30 may have different smooth shape, however, such as generally oblong, conical or cylindrical. The downstream end 30a of the elongated streamlined body 30 may be truncated.

[0041] A plurality of first cross-flow injection nozzles 32 and a plurality of second cross-flow injection nozzles 33 are provided on the elongated streamlined body 30 at respective axial locations. In one embodiment, the first cross-flow injection nozzles 32 are all at a first axial location and the second cross-flow injection nozzles 33 are all at a second axial location. Moreover, the second cross-flow injection nozzles 33 are axially displaced downstream of the first cross-flow injection nozzles 32. Thus the second cross-flow injection nozzles 33 are arranged nearer to the outlet of the second-stage combustion chamber 20 than the first cross-flow injection nozzles 32.

[0042] The first cross-flow injection nozzles 32 and the second cross-flow injection nozzles 33 are fluidly coupled to a fuel gas supply line 35 and to a fuel oil supply line 36, respectively. Terminal portions of the fuel gas supply line 35 and of a fuel oil supply line 36 are accommodated inside the elongated streamlined body 30. Accordingly, fuel gas and fuel oil may be separately fed to the second-stage combustion chamber 20. In addition, fuel oil is supplied at a location displaced axially downstream with respect to the fuel gas.

[0043] Fuel gas is injected through the first cross-flow injection nozzles 32 in a direction substantially perpendicular to an axis B of the axial lance injector 16. The second cross-flow injection nozzles 33 may be inclined to inject fuel oil in an inclined direction, that form an injection angle α with the axis B of the axial lance injector 16. The angle α may be comprised between 30° and 90°. Hence, due to the orientation of the second cross-flow injection nozzles 33, fuel oil is injected in the second-stage combustion chamber with a non-zero axial component of velocity. Radial and/or inclined sleeves (not shown) may be provided as desired to increase penetration of fuel gas and fuel oil, respectively.

[0044] The flame stabilizer device 23 is arranged downstream of the first cross-flow injection nozzles 32 and of the second cross-flow injection nozzles 33 and is configured to anchor the flame selectively at one of a plurality of flame locations. In one embodiment, the flame stabilizer device 23 is controlled by the controller 7 and comprises a full-load flame stabilizer 40 at a downstream end of the elongated streamlined body 30 and a at least one partial-load flame stabilizer 41 between the second cross-flow injection nozzles 33 and the full-load flame stabilizer 40.

[0045] The full-load flame stabilizer 40 comprises a set of full-load electrodes 40a on the elongated streamlined body 30 and a full-load voltage supply line 40b running inside the elongated streamlined body 30. Through the full-load electrodes 40a, the full-load flame stabilizer 40 produces sparks across the second-stage combustion chamber 20 and causes ignition of the mixture flowing through the second-stage combustion chamber 20 irrespective of temperature conditions and of the self-ignition time of the mixture. In this respect, the self-ignition time of the mixture may be even so long that the mixture would not self-ignite within the second-stage combustion chamber 20, but the full-load flame stabilizer 40 is in any case capable of stabilizing the flame at the downstream end of the elongated streamlined body 30.

[0046] The partial-load flame stabilizer 41 comprises a set of partial-load electrodes 41a on the streamlined body 30 and an upstream voltage supply line 41b. The partial-load electrodes 41a are arranged between the second cross-flow injection nozzles 33 and the full-load flame stabilizer 40.

[0047] The full-load flame stabilizer 40 and the partial-load flame stabilizer 41 are selectively activated by the controller 7 on the basis of the load determined for the gas turbine assembly 1. When the load exceeds a high load threshold, the controller 7 activates the full-load flame stabilizer 40 and deactivates the partial-load flame stabilizer 41, thus setting a current flame location at the downstream end of the elongated streamlined body 30. Instead, when the load is below a low load threshold, the controller 7 activates the partial-load flame stabilizer 41 and deactivates the full-load flame stabilizer 40. Accordingly, the current flame location is moved upstream towards the crossflow injection nozzles 32, 33. The low load threshold does not exceed the high load threshold. In addition, the controller 7 controls an inlet gas temperature of hot gas flowing from the first-stage combustor 12 to the second-stage combustor 13. For the purpose of controlling the inlet gas temperature, the controller 7 may act e.g. on a power split or power ratio of power delivered by the first-stage combustor 12 to power delivered by the second-stage combustor 13, and/or on a flow of dilution air admixed to the hot gas from the first-stage combustor 12 before entering the second-stage combustor 13. The controller 7 uses temperature control to help set a current flame location at an upstream region of the second-stage combustion chamber 20 (by increasing the inlet gas temperature at partial-load, with or without the aid of a flame stabilizer) or at a downstream region of the outlet of the second-stage combustion chamber 20 (by decreasing the inlet gas temperature at full-load; the full-load flame stabilizer 40 causes ignition of the mixture flowing through the second-stage combustion chamber 20 irrespective of temperature conditions, so the self-ignition time of the mixture may be even so long that the mixture would not self-ignite within the second-stage combustion chamber 20).

[0048] Vortex generators 42 may be provided upstream of the second-stage combustion chamber 20 on the inner liner 25, for example in the transition region 32. In one embodiment, the vortex generators 42 are configured to cause flow swirl by adding tangential component of velocity. The vortex generators 42 may be e.g. in the form of prismatic projections (see figure 4 by way of example), baffles, deflectors, lobes superficial roughness of the inner liner 25 or have any other suitable shape.

[0049] In another embodiment of the invention, illustrated in figures 5 and 6, at least one of the first cross-flow injection nozzles, here designated by numeral 132, is axially displaced with respect to the other first cross-flow injection nozzles 132. For example, the first cross-flow injection nozzles 132 may be staggered in the axial direction and arranged along a helical line on the elongated streamlined body 30 with uniform spacing in the circumferential direction.

[0050] Likewise, at least one of the second cross-flow injection nozzles, here designated by numeral 133, is axially displaced with respect to the other second cross-flow injection nozzles 133. For example, the second cross-flow injection nozzles 133 are staggered in the axial direction and arranged along a helical line on the elongated streamlined body 30 with uniform spacing in the circumferential direction.

[0051] Figure 7 shows another embodiment of the invention. In this case, the flame stabilizer device, here designate by numeral 223, comprises a change in cross section of the second-stage combustion chamber, here 220, in the axial direction. In particular, the change in cross section is configured to cause gas flowing through the second-stage combustion chamber to recirculate at the downstream flame location and cause flow stagnation. The change in cross section may be a sharp annular edge, as in the example illustrated in figure 7.

[0052] Finally, it is evident that the described combustor may be subject to modifications and variations, without departing from the scope of the present invention, as defined in the appended claims.

Claims

1. A combustor of a gas turbine, comprising:

a first-stage combustor (12) and a second-stage combustor (13), wherein the second-stage combustor (13) is arranged downstream of the first-stage combustor (12) and includes a second-stage combustion chamber (20; 220) extending along an axial direction;
an axial lance injector (16);
a flame stabilizer device (23; 223);
wherein the axial lance injector (16) comprises:

an elongated streamlined body (30) extending in the axial direction from the first-stage combustor (12) into the second-stage combustion chamber (20; 220) through a transition region (28) of the second-stage combustor (13), wherein the elongated streamlined body (30) and the transition region (28) are configured to prevent gas flowing from the first-stage combustor (12) to the second-stage combustion chamber (20; 220) from recirculating in the transition region (28);
a plurality of first cross-flow injection nozzles (32; 132) and a plurality of second cross-flow injection nozzles (33; 133) provided on the elongated streamlined body (30) at respective axial locations;
and wherein the flame stabilizer device (23; 223) is arranged downstream of the first cross-flow injection nozzles (32; 132) and of the second cross-flow injection nozzles (33; 133).

2. The combustor of claim 1, wherein the second cross-flow injection nozzles (33; 133) are axially displaced downstream of the first cross-flow injection nozzles (32; 132) .

3. The combustor of claim 2, wherein the first cross-flow injection nozzles (32; 132) are fluidly coupled to a fuel gas supply line (35) and the second cross-flow injection nozzles (33; 133) are fluidly coupled to a fuel oil supply line (36).

4. The combustor of claim 2 or 3, wherein at least one of the first cross-flow injection nozzles (32; 132) is axially displaced with respect to the other first cross-flow injection nozzles (32; 132).

5. The combustor of any one of claims 2 to 4, wherein the first cross-flow injection nozzles (32; 132) are staggered in the axial direction.

6. The combustor of any one of claims 2 to 5, wherein at least one of the second cross-flow injection nozzles (33; 133) is axially displaced with respect to the other second cross-flow injection nozzles (33; 133).

7. The combustor of any one of claims 2 to 6, wherein the second cross-flow injection nozzles (33; 133) are staggered in the axial direction.

8. The combustor of any one of the preceding claims, wherein the second cross-flow injection nozzles (33; 133) are oriented at such an angle (α) that fuel oil is injected in the second-stage combustion chamber (20; 220) with a non-zero axial component of velocity.

9. The combustor of any one of the preceding claims, comprising vortex generators (42) upstream of the second-stage combustion chamber (20; 220).

10. The combustor of any one of the preceding claims, wherein the flame stabilizer device (23; 223) comprises a full-load flame stabilizer (40) at a downstream end of the elongated streamlined body (30).

11. The combustor of claim 10, wherein the flame stabilizer device (23; 223) comprises at least one partial-load flame stabilizer (41) between the second cross-flow injection nozzles (33; 133) and the full-load flame stabilizer (40).

12. The combustor of any one of the preceding claims, wherein the flame stabilizer device (23; 223) comprises at least one of:

a downstream electrode system (40a, 41a), operable to provide ignition energy in the second-stage combustion chamber (20; 220) at least at one flame location; and
a change in cross section of the second-stage combustion chamber (20; 220) in the axial direction, the change in cross section being configured to cause gas flowing through the second-stage combustion chamber (20; 220) to recirculate at least at one flame location.

13. The combustor of any one of the preceding claims, wherein the first-stage combustor (12) comprises an upstream end-cap (31) and the elongated streamlined body (30) is supported at the upstream end-cap (31).

14. The combustor of any one of the preceding claims, wherein a flow channel is defined in the first-stage combustor (12) and in the second-stage combustor (13) around the elongated streamlined body (30) and a cross section of the flow channel changes gradually along the flow direction in the transition region (28).

15. A gas turbine assembly comprising a compressor section (2), a combustor assembly (3), a turbine section (5) and a controller (7), configured to operate the gas turbine assembly to provide a controlled power output, wherein the combustor assembly (3) includes a combustor according to any one of the preceding claims and the controller (7) is further configured to control a hot gas temperature of hot gas flowing from the first-stage combustor (12) to the second-stage combustor (13) so that the hot gas temperature is higher at partial-load and lower at full-load.

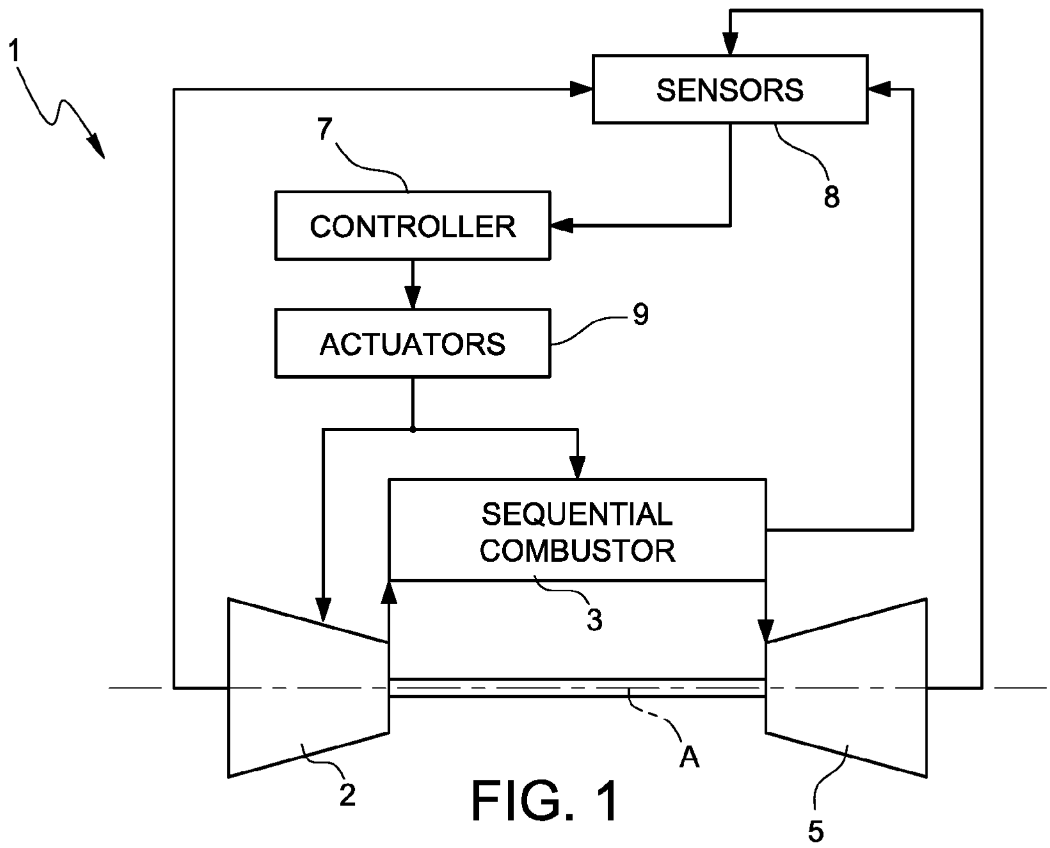
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FIG. 1

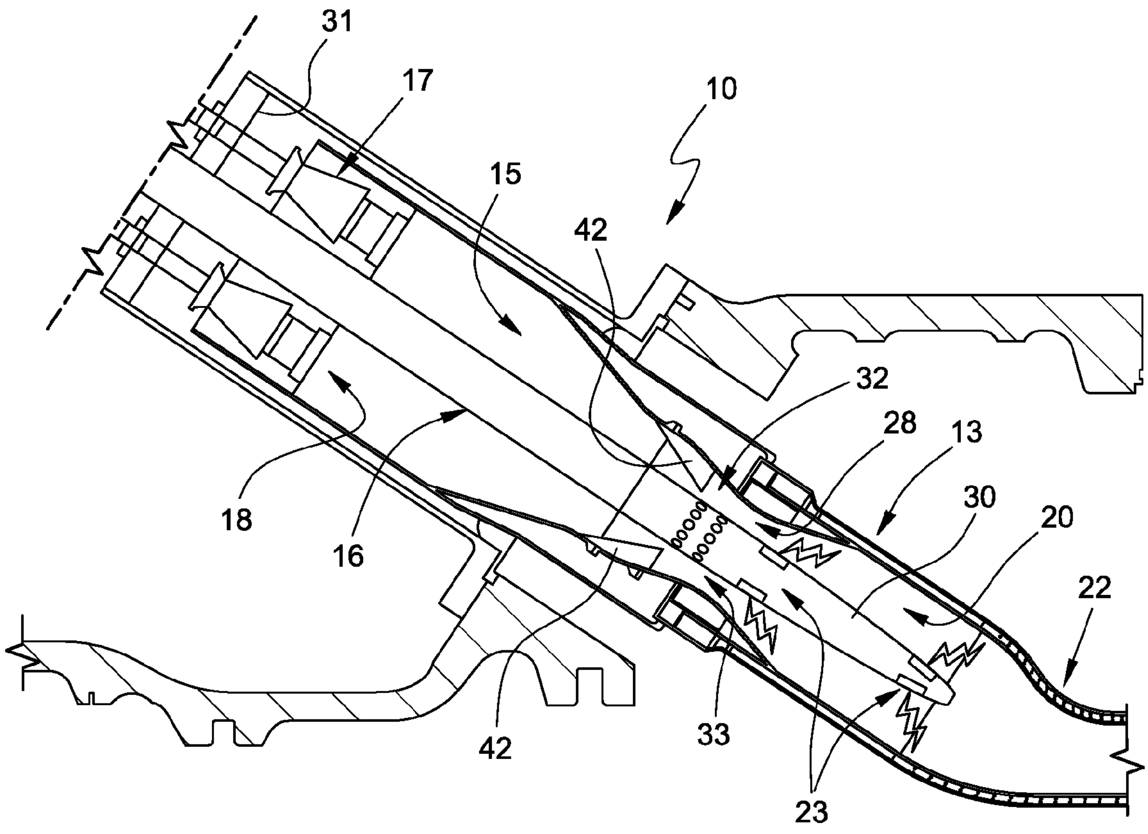
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FIG. 2

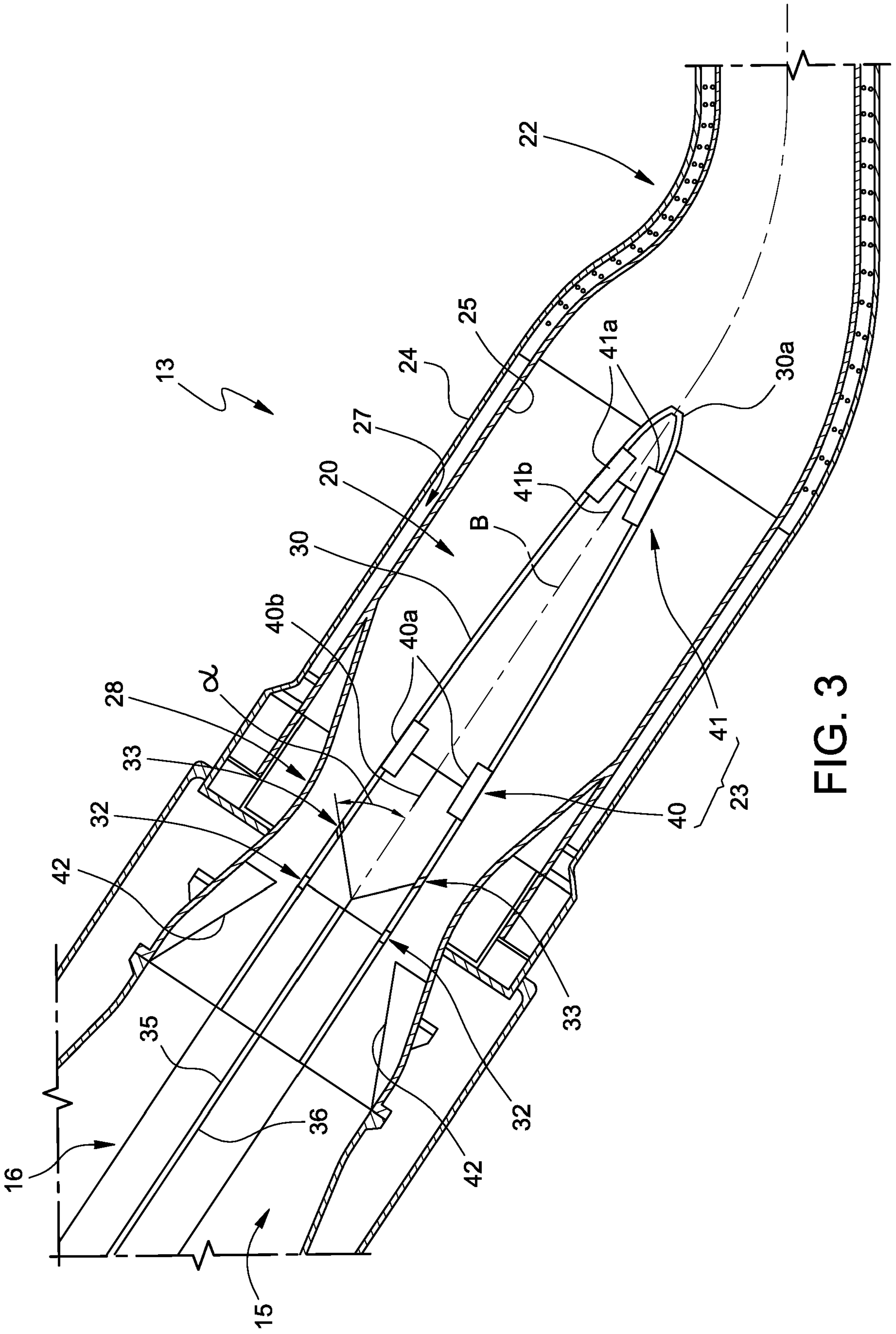
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FIG. 3

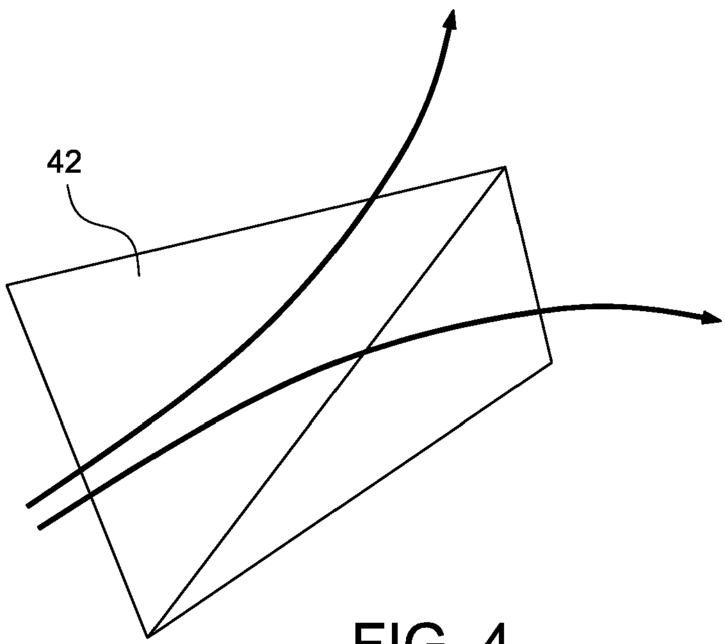

FIG. 4

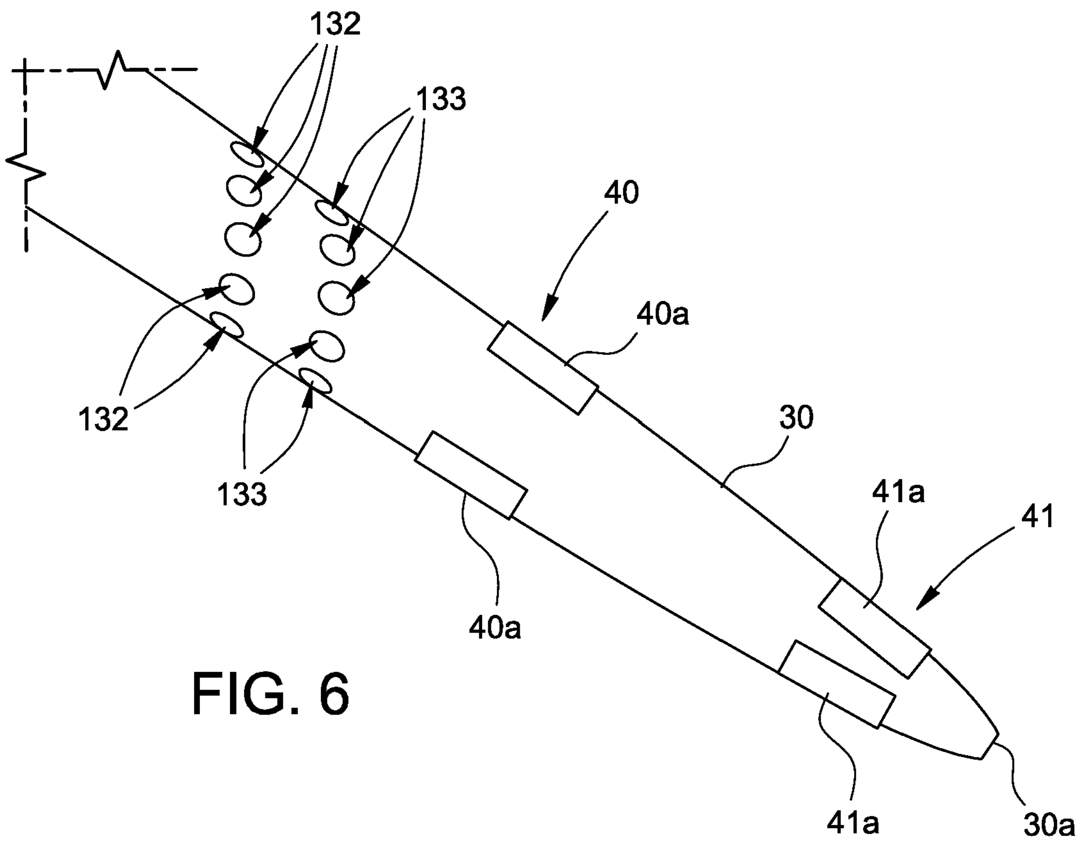

FIG. 6

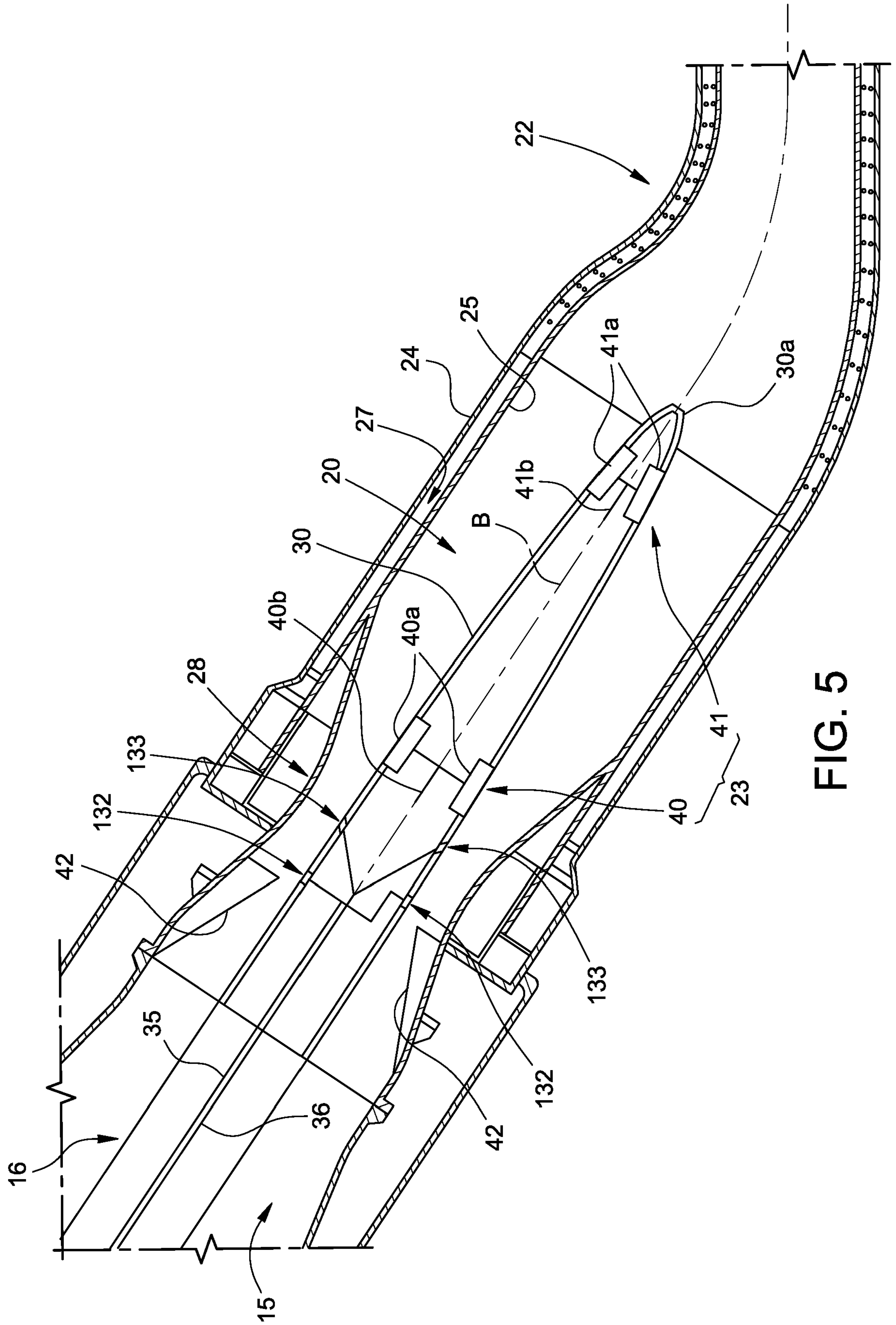
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FIG. 5

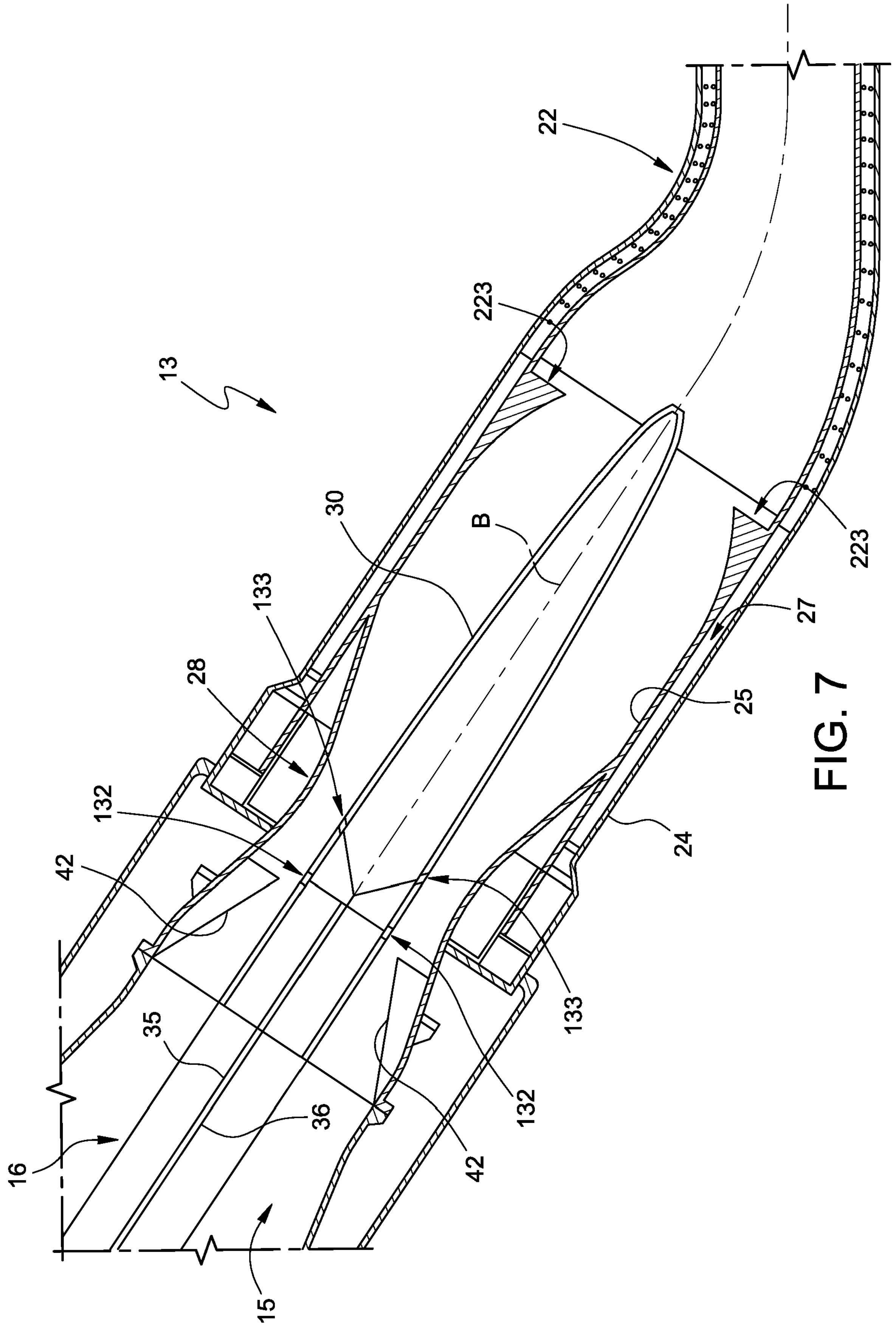

FIG. 7

Europäisches Patentamt
European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 17 20 1920

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 3 015 772 A1 (ALSTOM TECHNOLOGY LTD [CH]) 4 May 2016 (2016-05-04) * paragraph [0028] - paragraph [0043] * * paragraph [0049] - paragraph [0050] *	1-3,13 4-12,14	INV. F23R3/36 F23R3/34 F23C99/00
Y A	US 6 895 759 B2 (ALSTOM TECHNOLOGY LTD [CH]) 24 May 2005 (2005-05-24) * column 6, line 7 - line 65 * * column 7, line 40 - line 20; figures 1-7 *	4-8 1-3	
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