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(54) GAS TURBINE COMBUSTOR

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(57) **ABSTRACT**

A gas turbine combustor includes a pilot burner, provided at a top portion of a combustion liner having a combustion chamber defined therein, and a main burner of a premixing type disposed adjacent an outer periphery thereof. The pilot burner is provided with an inflow passage, provided in an upstream end portion to allow the compressed air from a radially outer area into a radially inner area, a plurality of fuel supply holes for injecting the fuel into the inflow passage in a direction perpendicular to the flow of the compressed air, a premixing passage for guiding the air-fuel mixture from the inflow passage in an axially downstream direction while the compressed air and the fuel are mixed together, and a plurality of premixed air-fuel mixture injection holes for injecting the premixed air-fuel mixture from the premixing passage into the combustion chamber.

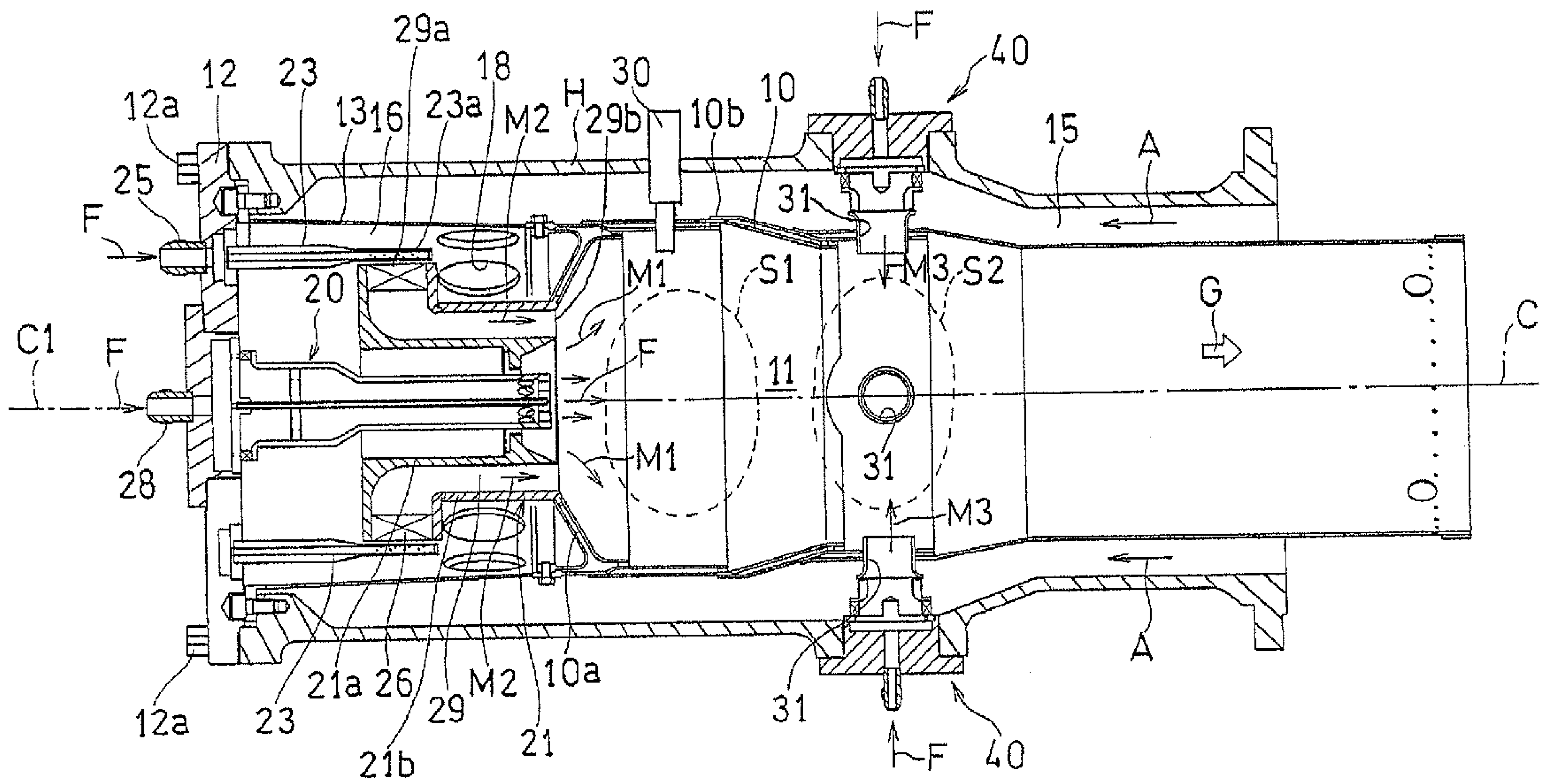
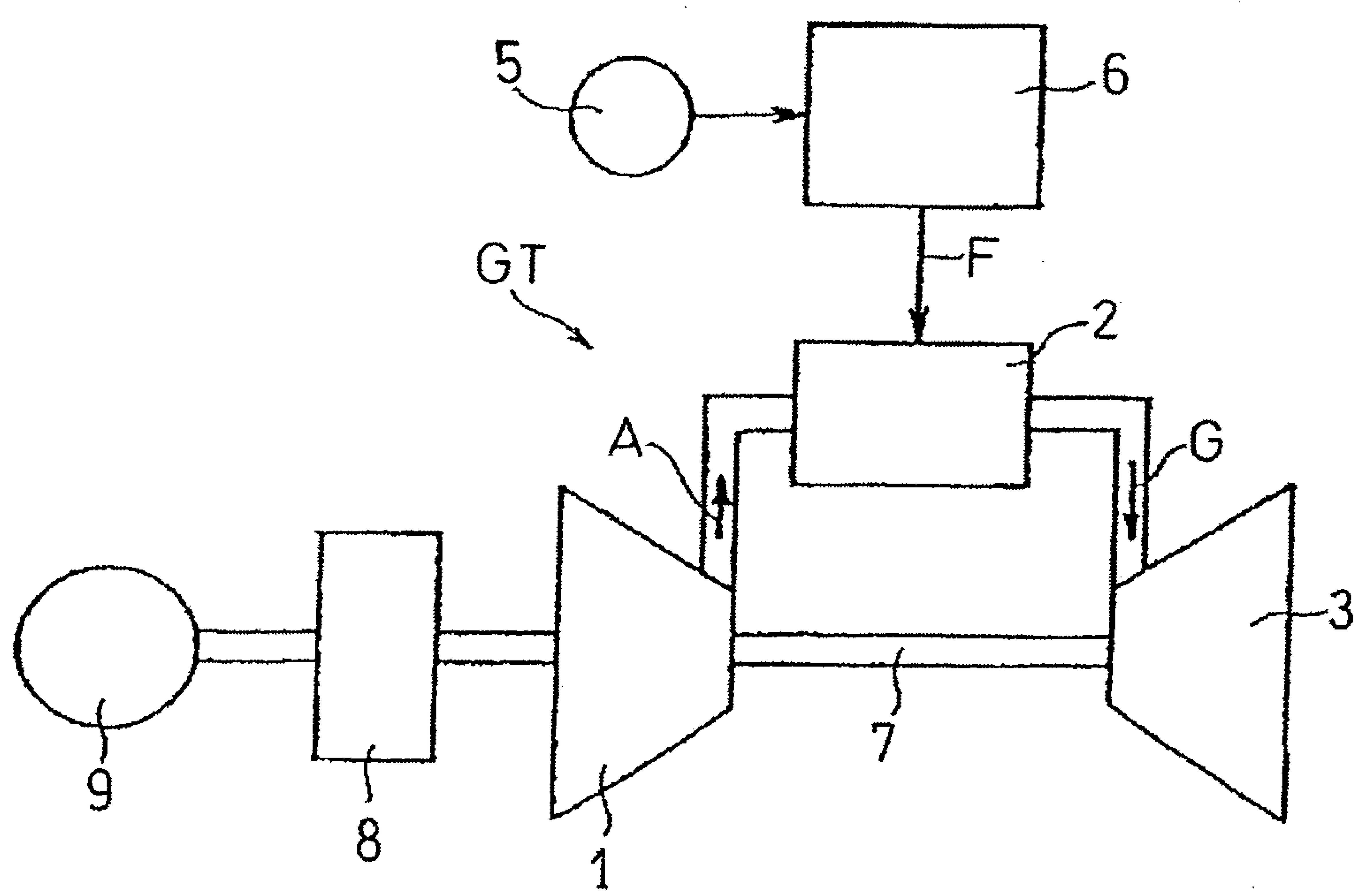


Fig. 1



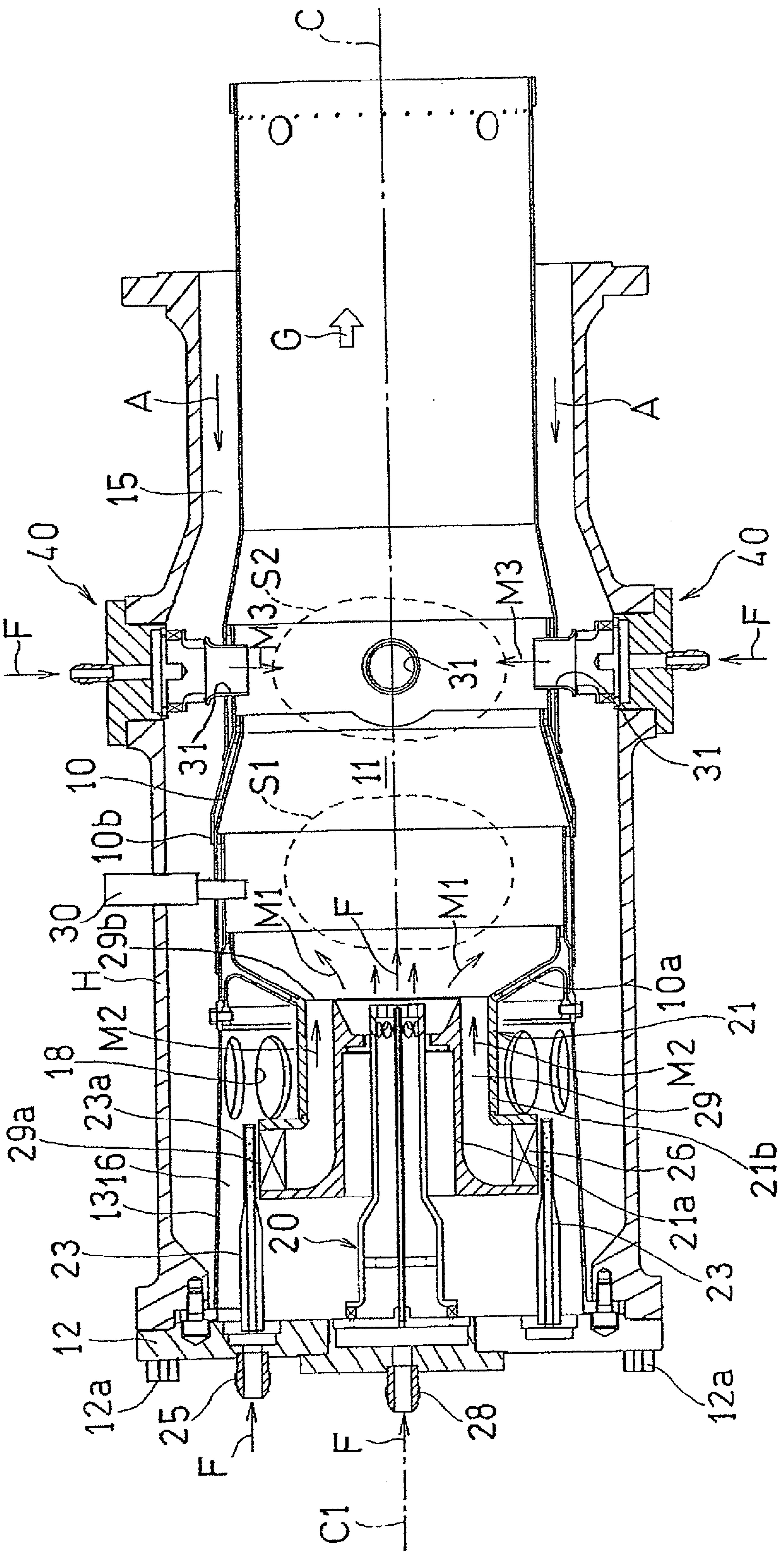

C
G
A
A
15
40
40
F
F
M3
S2
M3
31
31
31
11
S1
10
10b
30
29b
H
M1
F
M1
10a
21
M2
M2
18
23a
29
29a
16
13
26
21b
21a
23
20
23
12
12a
12a
25
28
F
F
C1

Fig. 2

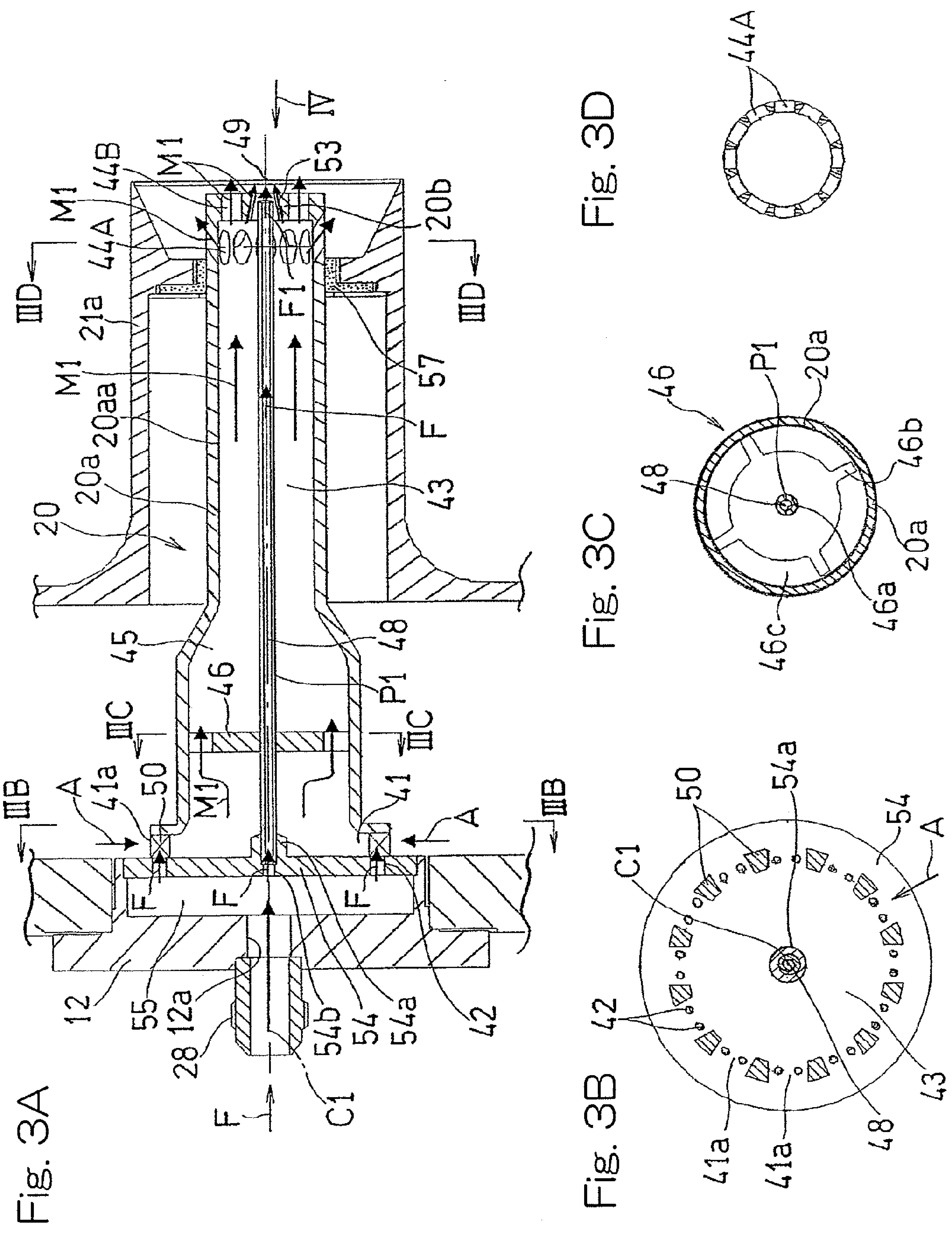


Fig. 3A

Fig. 3B

Fig. 3C

Fig. 3D

Fig. 4

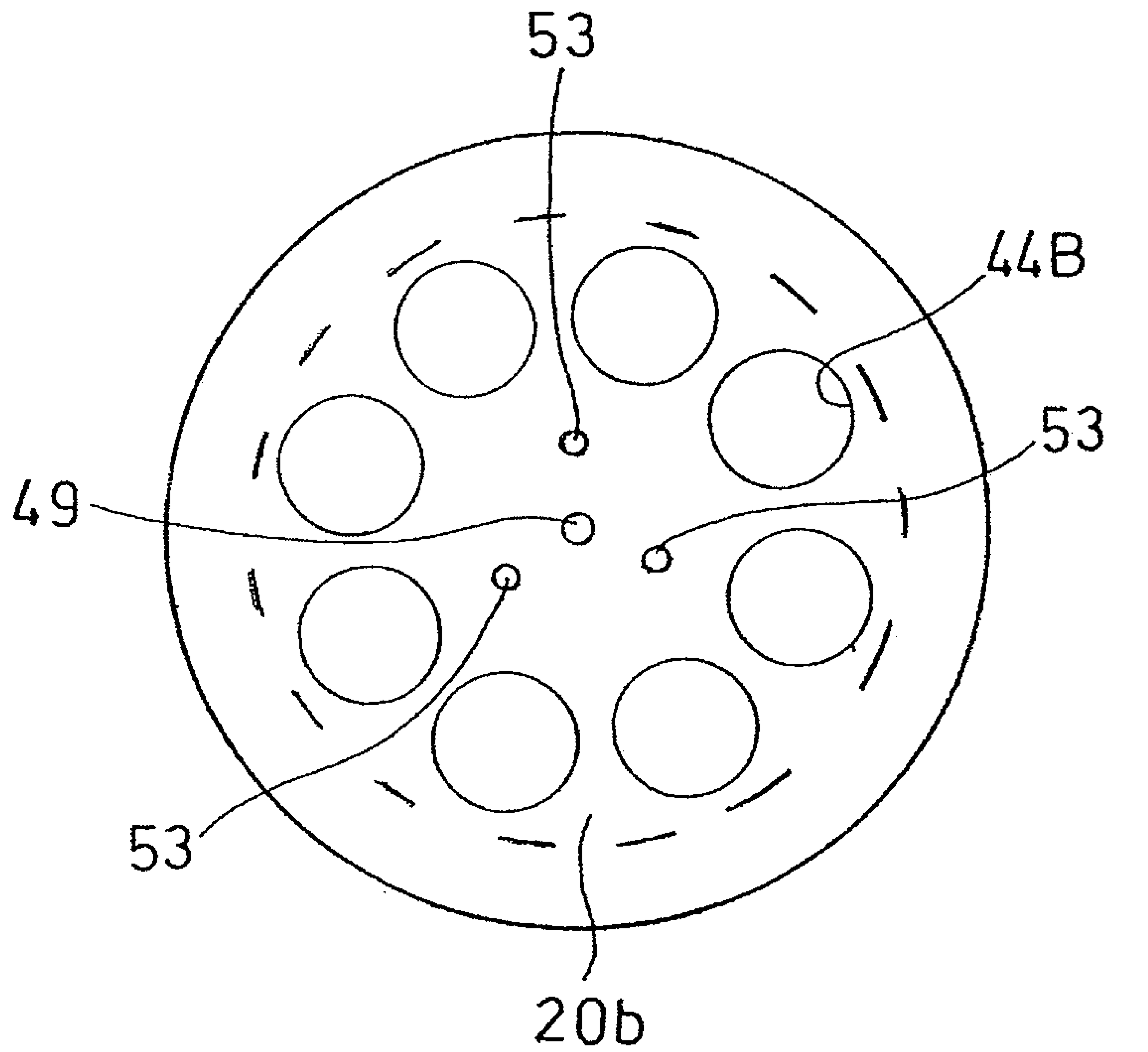
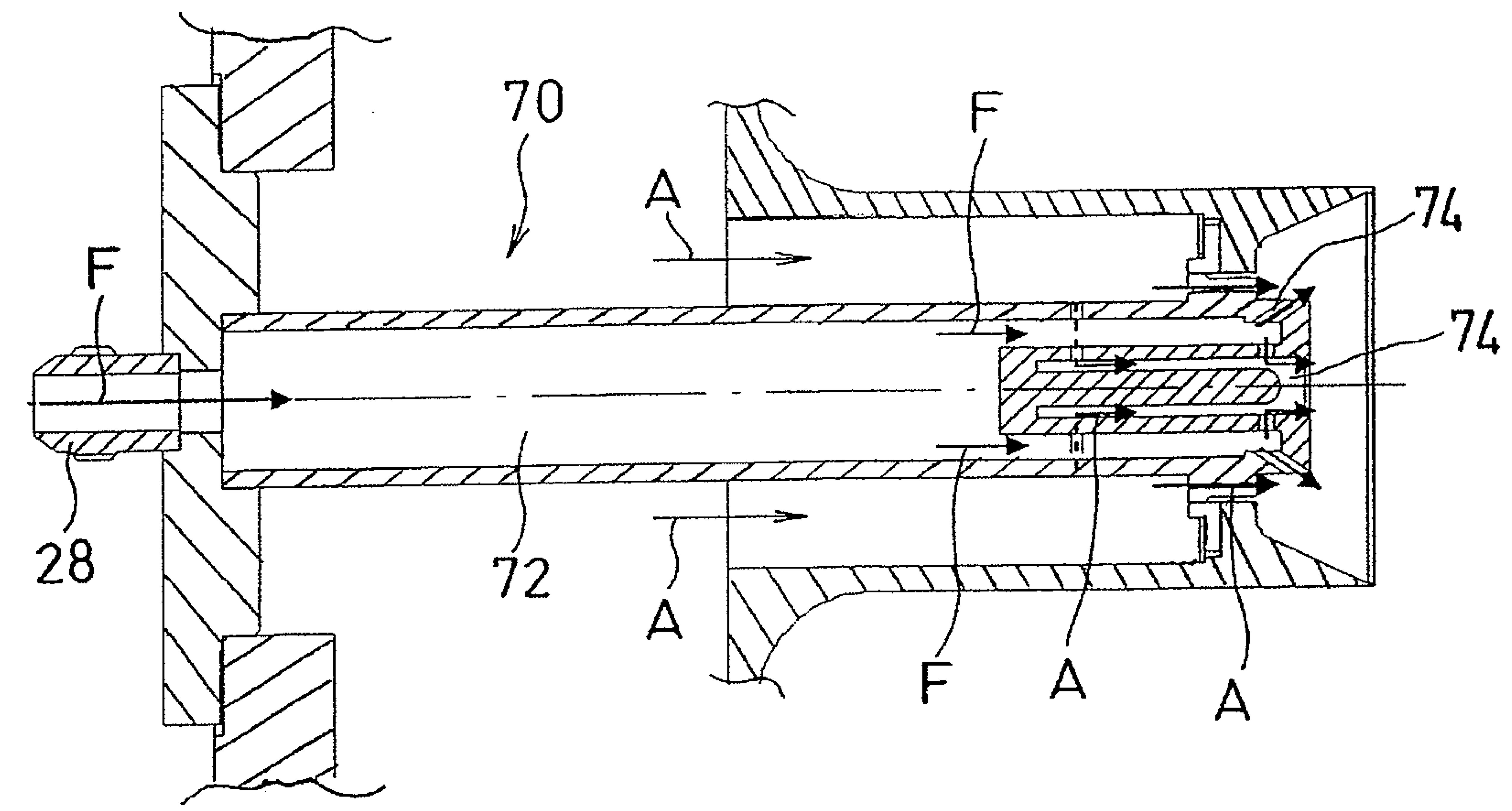


Fig. 5



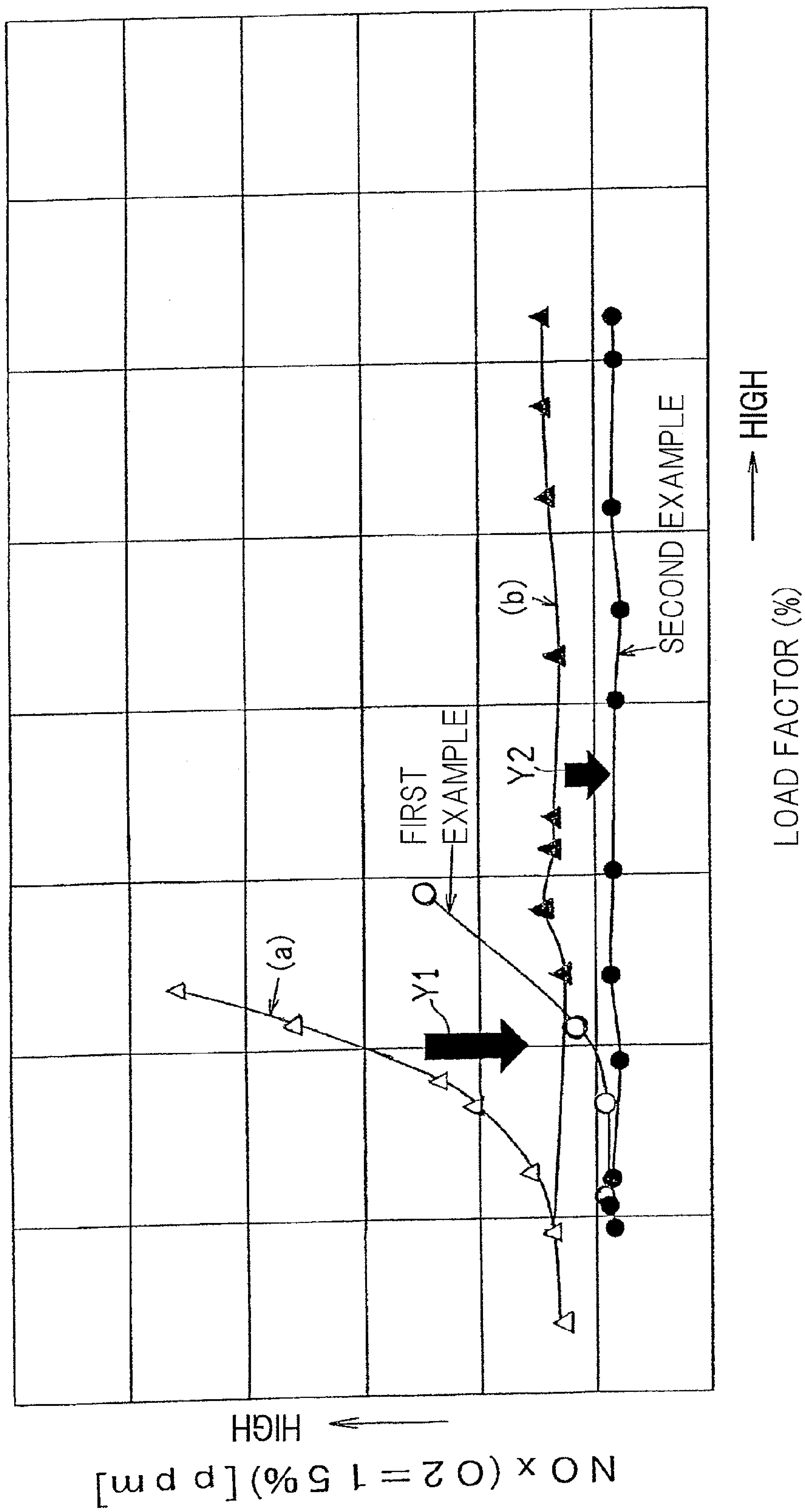

FIRST EXAMPLE
SECOND EXAMPLE
(a)
(b)
Y1
Y2
LOAD FACTOR (%)
HIGH
HIGH
NOx (O2 = 15%) [ppm]

Fig. 6

GAS TURBINE COMBUSTOR

CROSS REFERENCE TO THE RELATED APPLICATION

[0001] This application is a continuation application, under 35 U.S.C. §111(a), of international application No. PCT/JP2012/070061, filed Aug. 7, 2012, which claims priority to Japanese patent application No. 2011-192549, filed Sep. 5, 2011, the disclosure of which are incorporated by reference in their entirety into this application.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a gas turbine combustor capable of suppressing the emissions of nitrogen oxides (hereinafter referred to as NOx).

[0004] 2. Description of Related Art

[0005] The gas turbine apparatuses are subjected to severe environmental standards regarding the composition of exhaust gases emitted from a turbine during the operation thereof. In particular, reduction of the emissions of NOx contained in the exhaust gases is sought for. As a method of reducing the NOx emission in the gas turbine apparatus, a technique of injecting water or vapor into a combustion chamber to lower the temperature of combustion flames has hitherto been employed. It has, however, been found that according to the above described method, a injecting equipment for injecting water or vapor is required, which results in an increase of costs. Problems have also been found in that the method that the heat exchange effectiveness of the apparatus tends to be lowered and that, if the quality of water used is aggravated, the life of the apparatus is shortened as a result of corrosion of the turbine. As a gas turbine apparatus designed to overcome those problems, a gas turbine apparatus has recently come to be suggested, in which a DLE (dry low emission) combustor effective to reduce the NOx emission is utilized without the use of water or vapor. In the DLE combustor of a type, instead of the pilot burner of a diffusive combustion type hitherto employed, a pilot burner of a premixing combustion type has been employed to thereby further reduce the NOx emission emitted from the turbine (See the Patent Document 1 listed below.).

PRIOR ART DOCUMENT

Patent Document

[0006] [Patent Document 1] JP Laid-open Patent Publication No. 2011-21875

SUMMARY OF THE INVENTION

[0007] It has, however, been found that in the case of the combustor of a type utilizing the premixing type pilot burner such as disclosed in the above mentioned patent document 1, premixed air-fuel mixture of a kind that is uniformly mixed with even concentration distribution cannot be obtained because the premixing length, in which fuel and a compressed air are mixed, is extremely short. Accordingly, no leaned premix combustion is ideally performed and, therefore, no satisfactory reduction of the NOx emission is expected.

[0008] In view of the foregoing, the present invention has for its object to provide a gas turbine combustor equipped with a pilot burner effective to accomplish a sufficient premixing of a compressed air and a fuel to realize the low NOx emission.

[0009] In order to accomplish the foregoing object of the present invention, a gas turbine combustor in accordance with the present invention to mix a compressed air, fed from a compressor, with a fuel to burn a resultant air-fuel mixture to be supplied to a turbine, comprises: a pilot burner provided in a top portion of a combustion liner defining a combustion chamber therein, a main burner of a premixing type located on an outer periphery side thereof, the pilot burner including: an inflow passage provided in an upstream end portion to allow the compressed air to inflow from a radially outer area into a radially inner area; a plurality of fuel supply holes to inject the fuel into the inflow passage in a direction perpendicular to the flow of the compressed air; a premixing passage to mix the compressed air and the fuel inflowed through the inflow passage and to guide the air-fuel mixture towards an axially downstream side; and a plurality of premixed air-fuel mixture injection holes to inject the premixed air-fuel mixture from the premixing passage into the combustion chamber.

[0010] According to the above described construction, in the inflow passage the compressed air and the fuel fed from the plurality of the fuel supply holes are supplied in a direction perpendicular to each other. Accordingly, by the action of a shearing force of the compressed air relative to the fuel, the mixing of the compressed air with the fuel is facilitated. Also, since the premixed air-fuel mixture is deflected 90° at the time it is introduced from the inflow passage into the premixing passage, a large turbulence occurs in the flow and the premixing is therefore facilitated. In addition, since the premixed air-fuel mixture is guided through the premixing passage in a direction axially upstream thereof, the premixing is further facilitated within this premixing passage. As a result, the uniform premixed air-fuel mixture having a minimized variation in concentration of the fuel can be obtained. Since this premixed air-fuel mixture is injected into the combustion chamber through the plurality of the premixed air-fuel mixture injection holes, a bias of the premixed air-fuel mixture within the combustion chamber is suppressed. Also, since the premixed air-fuel mixture is injected into the combustion chamber from the main burner of the premixing type disposed in an outer periphery of the pilot burner, the uniformly premixed air-fuel mixture having a minimized variation in concentration of the fuel, not the air-fuel mixture having an enriched concentration, is combusted within the combustion chamber over the entire operating region ranging from a low load operating region to a high load operating region. In view of this, the emissions of NOx may be reduced.

[0011] In one embodiment of the present invention, a fuel injection hole may be provided at a center portion of the pilot burner to inject a portion of a fuel for piloting purpose into the combustion chamber. According to this structural feature, since that portion of the fuel for the pilot burner can be injected into the combustion chamber through the fuel injection hole provided at the center portion of the pilot burner, the ignitability may be increased and a flame stability can be secured.

[0012] In one embodiment of the present invention, a carbon removal injection hole may be formed in the vicinity of a downstream side of the fuel injection hole to supply a portion of the premixed air-fuel mixture within the premixing passage. According to this structural feature, the concentration of the fuel injected through the fuel injection hole into the combustion chamber may be made lower by means of the premixed air-fuel mixture from the carbon removal injection hole to there by avoid an undesirable generation of soot (carbon) which would be brought about by the excessive enrichment of the fuel. Accordingly, the fuel may be stably injected into the combustion chamber without allowing the fuel injection hole to be clogged with a deposition of carbon.

[0013] In one embodiment of the present invention, the premixing passage may include a speed increasing portion having a passage section that gradually reduces towards a downstream side. According to this structural feature, the flow through the speed increasing portion results in an increase of the flow velocity of the premixed air-fuel mixture and, therefore, it is possible to avoid an undesirable back fire from occurring from the side of the combustion chamber to the premixing passage.

[0014] In one embodiment of the present invention, a mixing facilitation member may be provided on an upstream side of the speed increasing portion in the premixing passage to facilitate a premixing by deflecting the premixed air-fuel mixture radially outwardly. According to this structural feature, the premix made up of the compressed air and the fuel, which has been introduced into the premixing passage, is deflected towards a radially outer side by the mixing facilitation member and, therefore, the premixing is facilitated by such deflection. Also, since the mixing facilitation member is provided in a portion of the premixing passage, which has a large passage section and is positioned on the upstream side of the speed increasing portion, an undesirable increase of the passage resistance by the mixing facilitation member can be suppressed a quantity corresponding to that in which the flow velocity is not high.

[0015] In one embodiment of the present invention, the inflow passage may have an annular inflow opening, the inflow passage including a plurality of guide pieces positioned radially inwardly of the annular inflow opening to guide the compressed air towards a center of the inflow passage. According this structural feature, since the compressed air is introduced from the annular inflow port towards a center portion, the compressed air from the inflow port collide at the center portion of the inflow passage accompanied by an enhancement of the turbulence and, as a result, the mixing with the fuel can be facilitated.

[0016] In one embodiment of the present invention, the fuel supply holes may be arranged at portions between the neighboring guide pieces. According to this structural feature, since the plurality of the fuel supply holes are arranged at portions between the neighboring guide pieces, the fuel may be injected at multiple points and, also, since the fuel divided in a circumferential direction by the guide pieces is supplied into the inflow passage, a uniformly premixed air-fuel mixture having a minimized variation in concentration distribution of the fuel may be obtained.

[0017] Any combination of at least two constructions, disclosed in the appended claims and/or the specification and/or the accompanying drawings should be construed as included within the scope of the present invention. In particular, any combination of two or more of the appended claims should be equally construed as included within the scope of the present invention.

[0018] In any event, the present invention will become more clearly understood from the following description of embodiments thereof, when taken in conjunction with the accompanying drawings. However, the embodiments and the drawings are given only for the purpose of illustration and explanation, and are not to be taken as limiting the scope of the present invention in any way whatsoever, which scope is to be determined by the appended claims. In the accompanying drawings, like reference numerals are used to denote like parts throughout the several views.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. **1** is a schematic structural diagram showing a gas turbine generator to which a gas turbine combustor according to one embodiment of the present invention is applied;

[0020] FIG. **2** is a longitudinal sectional view of the gas turbine combustor shown in FIG. **1**;

[0021] FIG. **3**A is a longitudinal sectional view, on an enlarged scale, showing a pilot burner employed in the gas turbine combustor shown in FIG. **1**;

[0022] FIG. **3**B is a cross sectional view taken along the line IIIB-IIIB in FIG. **3**A;

[0023] FIG. **3**C is a cross sectional view taken along the line IIIC-IIIC in FIG. **3**A;

[0024] FIG. **3**D is a cross sectional view taken along the line IIID-IIID in FIG. **3**A;

[0025] FIG. **4** is an end view, on an enlarged scale, showing the pilot burner as viewed along the arrow IV in FIG. **3**A;

[0026] FIG. **5** is a longitudinal sectional view showing the conventional diffusive type pilot burner as a comparative example; and

[0027] FIG. **6** is a chart showing the relation between the load factor and the NOx emission in the gas turbine combustor.

DETAILED DESCRIPTION OF EMBODIMENTS

[0028] Hereinafter, a gas turbine combustor designed in accordance with an embodiment of the present invention will be described in detail with reference to the accompanying drawings. Referring to FIG. **1** showing a schematic structure of a gas turbine generator in which the gas turbine combustor of the embodiment is employed, the gas turbine generator GT includes, as principal constituent elements thereof, a compressor **1**, a combustor **2** and a turbine **3**. The combustor **2** is provided with a fuel supply device **5** and a fuel control device **6**. A compressed air A, fed from the compressor **1**, and fuel F fed from the fuel supply device **5** through the fuel control device **6** are burned within the combustor **2** to produce a combustion gas G of high temperature and high pressure, which is in turn supplied to the turbine **3** to drive the turbine **3**. The compressor **1** is driven by the turbine **3** through a rotary shaft **7**. The turbine **3** also drives an electric generator **9** through a reduction gear unit **8**.

[0029] As shown in a longitudinal sectional view in FIG. **2**, the combustor **2** is of a reverse flow can type in which the compressed air A introduced into such combustor **2** and the combustion gas G flows in respective directions counter to each other within the combustor **2**. The combustor **2** includes a plurality of cylindrical housings H arranged circumferentially of a circle coaxial with the rotary shaft **7**. Each of those housings H accommodates a substantially cylindrical combustion liner **10** therein, in which a combustion chamber **11** is formed. Each of the housings H has a head end (a left end portion as viewed in FIG. **2**), which is a tip end side thereof, and an end cover **12** is secured to such head end by means of a plurality of bolts **12***a*.

[0030] A cylindrical support **13** positioned inside of the housing H has its base end portion connected with an upstream side of the housing H. This cylindrical support **13** has a tip end portion (a right end portion as viewed in FIG. **2**) to which a top portion **10***a* of the combustion liner **10** is secured and, hence, the combustion liner **10** is supported by the housing H through the cylindrical support **13**. Between a peripheral wall **10***b* of the combustion liner **10** and the housing H enclosing the combustion liner **10** an annular air passage **15** is defined for introducing the compressed air A fed from the compressor **1** (shown in FIG. **1**) in a direction towards the top portion **10***a* of the combustion liner **10**, that is, in a direction towards an upstream side. An air introduction chamber **16** is defined inside of the cylindrical support **13** and the support barrel is provided with a plurality of air introduction holes **18** through which the compressed air A is introduced into the air introduction chamber **16**.

[0031] A single pilot burner **20** of a premixing type is provided within the combustion chamber **11** at a center area of the top portion **10***a* of the combustion liner **10** for injecting a portion of the fuel F directly into the combustion chamber **11** and, also, injecting a premixed air-fuel mixture M**1** formed by mixing the fuel F and the compressed air A together. This pilot burner **20** has a base end fluid connected with a pilot fuel introduction port **28** provided in the end cover **12**. A single main burner **21** of a premixing type for injecting a premixed air-fuel mixture M**2**, formed by mixing the fuel F and the compressed air A together, from a premixing passage **29** into the combustion chamber **11** is provided so as to encircle an outer periphery of the pilot burner **20**.

[0032] The main burner **21** includes a main inner peripheral wall **21** a and a main outer peripheral wall **21***b*, which cooperatively define therebetween the premixing passage **29** of a longitudinally L-sectioned configuration. This premixing passage **29** has an upstream end opening in a direction radially outwardly thereof to define an annular air intake opening **29***a*, and a plurality of main fuel nozzles **23** are arranged at respective locations radially outwardly of the annular air intake opening **29***a* and spaced equidistantly from each other in a direction circumferentially of the main burner **21**. A plurality of main fuel injecting ports **23***a* are defined in a portion of the main fuel nozzle **23** that faces the annular air intake opening **29***a*. The main fuel nozzle **23** has a base end connected with a main fuel introduction port **25** defined in the end cover **12**. The annular air intake opening **29***a* has a swirler **26** disposed therein. The fuel F supplied from the main fuel introduction port **25**, together with the compressed air A inflowing from the air intake opening **29***a*, is swirled by the swirler **26** and is, after having been premixed within the annular premixing passage **29**, injected from an annular premix injection opening **29***b* into the combustion chamber **11** as a premixed air-fuel mixture M**2**.

[0033] The fuel F from the fuel supply device **5** shown in FIG. **1** is supplied through the fuel control device **6** to both of the pilot fuel introduction port **28** and the main fuel introduction port **25**.

[0034] An ignition plug **30** is provided in an upstream portion of the peripheral wall **10***b* of the combustion liner **10** with its tip end positioned inside of the combustion chamber **11**. The ignition plug **30** extends through the housing H so as to be fixed to the housing H. At the time of start-up, the premixed air-fuel mixture M**1** injected into the combustion chamber **11** through the pilot burner **20** of the premixing type is ignited by such ignition plug **30**. Under a low load operating condition, only the pilot burner **20** of the premixing type is activated. Thereafter, under a normal operating condition, in which a load higher than that during the low load operating condition is applied, the premixed air-fuel mixture M**2** injected into the combustion chamber **11** through the main burner **21** and the premixed air-fuel mixture M**1** injected into the combustion chamber **11** through the pilot burner **20** of the premixing type are simultaneously burned so that a first combustion region S**1** consequently is defined in an upstream portion of the combustion liner **10** and on a downstream side of the main burner **21**.

[0035] On a downstream side of the first combustion region S**1** within the combustion liner **10**, a plurality of, for example, four, air holes **31** are provided having been spaced an equal distance from each other in a circumferential direction of the combustion liner **10**. Respective portions of the housings H facing the air holes **31** have supplemental burners **40** of a premixing type fitted thereto. A tip end portion of each of the supplemental burners **40** is positioned inside of the combustion chamber **11** through the corresponding air hole **31**. In this way, each of the supplemental burner **40** is disposed having extended through the peripheral wall **10***b* of the combustion liner **10** at a position downstream side of the main burner **21** in the combustion liner **10** so that a premixed air-fuel mixture M**3** for use by the respective supplemental burner **40** can be injected into the combustion liner **10** to form a second combustion region S**2** on a downstream side of the first combustion region S**1** within the combustion chamber **11**.

[0036] FIGS. **3**A to **3**D illustrate the details of the pilot burner **20**. As shown in FIG. **3**A, the pilot burner **20** has a straight burner axis C**1** coaxial with a longitudinal axis C, shown in FIG. **2**, of the combustion liner **10** and includes an inflow passage **41** for the compressed air A, a premixing passage **43** and a plurality of first and second mixture injection holes **44**A and **44**B defined in a downstream end portion. The inflow passage **41** is provided at an upstream end portion (left end side as viewed in FIG. **3**A) so as to allow the compressed air A to flow thereinto from a radially outer area to a radially inner area. The premixing passage **43** is operable to mix the compressed air A and the fuel F inflowed through the inflow passage **41** and to guide the air-fuel mixture towards an axially downstream side (a right end side shown in FIG. **3**A). The resultant air-fuel mixture M**1** within the premixing passage **43** are injected through the premixed air-fuel mixture injection holes **44**A and **44**B into the combustion chamber **11** (shown in FIG. **2**).

[0037] The inflow passage **41** has an outer periphery formed with an annular inflow opening **41***a* defined therein. A plurality of fuel supply holes **42** are provided radially inwardly of the inflow opening **41***a* for injecting the fuel F in a direction perpendicular to the direction of flow of the compressed air A in the inflow passage **41**. The premixing passage **43** referred to above has a speed increasing portion **45** having a passage sectional area that gradually decreases towards a downstream side. The premixed air-fuel mixture M**1** is injected through the premixed air-fuel mixture injection holes **44**A and **44**B after the flow velocity thereof has been increased as it pass through the speed increasing portion **45**.

[0038] A mixing facilitation member **46** for facilitating mixing by deflecting the premixed air-fuel mixture M**1** in a direction radially outwardly thereof is provided on an upstream side of the speed increasing portion **45** of the premixing passage **43**. Also, a flame holding fuel passage **48** extending in a direction along the axis C**1** is provided in a center portion of the pilot burner **20** with its downstream tip end communicated with a fuel injection hole **49**. A portion of the fuel F for the pilot burner is injected into the combustion chamber (shown in FIG. **2**) through the fuel injection hole **49**. The flame holding fuel passage **48** is defined by the hollow of a center tube P**1**. The premixing passage **43** is an annular passage that is defined between a cylindrical body **20***a* forming a part of an outer wall of the premixing passage **43**, closed at one end thereof and having a constricted portion (the speed increasing portion) **45**, and the fuel tube P**1** forming the flame holding fuel passage **48** at a center portion. The fuel injection hole **49** is defined in a center portion of a tip end wall **20***b* of the pilot nozzle **20** and is in the form of a round hole of a diameter smaller than that of the flame holding fuel passage **48**. In the embodiment now under discussion, the cylindrical body **20***a* and the tip end wall **20***b* are formed integrally with each other.

[0039] As shown in FIG. **3**B, the annular inflow opening **41***a* is provided with a plurality of, for example, twelve guide pieces **50** for guiding the compressed air A from the inflow opening **41***a* in a direction towards the center portion and those guide pieces **50** are spaced an equal distance from each other in a circumferential direction thereof. Those guide pieces **50** are disposed between a disc-shaped nozzle plate **54** and an upstream end portion of the cylindrical body **20***a* and are fixed to the nozzle plate **54** and to the cylindrical body **20***a* by means of, for example, welding.

[0040] In the vicinity of an outer peripheral portion of the nozzle plate **54**, the plurality of the fuel supply holes **42** are arranged in a fashion coaxial with the nozzle plate **54**. The fuel supply holes **42** referred to above are so opened in a direction towards a radially inner area of the combustion liner **10** while communicated with a fuel reservoir space **55**. A fuel introduction passage **12***a* for introducing the fuel F into the fuel reservoir space **55** is formed between the nozzle plate **54** and an end plate **12**. The fuel F flows into the fuel reservoir space **55** after having passed through the fuel introduction port **28** and then through the fuel introduction passage **12***a*. A portion of the fuel F is guided into the flame holding fuel passage **48** and the remaining portion of the fuel F is supplied into the inflow passage **41** through the fuel supply holes **42**. Also, the nozzle plate **54** has a center portion thereof formed with a center projection **54***a* having its tip end representing an inverted conical shape. This center projection **54***a* has a length somewhat greater than the height (length as measured along the axial direction) of any of the guide pieces **50**.

[0041] In the annular inflow passage **41**, the compressed air A having flowed through the inflow opening **41***a* flows from a radially outer area in a direction radially inwardly thereof into gaps each delimited between the neighboring guide pieces **50**, **50**. In the illustrated embodiment, the number of the fuel supply holes **42** employed between the neighboring guide pieces **50** and **50** for injecting the fuel F in a direction perpendicular to the direction of flow of the compressed air A is chosen to be two and, therefore, the total number of the fuel supply holes **42** amounts to twenty four. Accordingly, since the plurality of the fuel supply holes **42** are arranged in the gaps delimited between the neighboring guide pieces **50**, **50**, the fuel F is injected at multiple points and, also, since the fuel F divided in a circumferential direction by the guide pieces **50** is supplied into the inflow passage **41**, a uniformly premixed air-fuel mixture having a minimized variation in concentration of the fuel F may be obtained.

[0042] In this instance, the compressed air A is introduced towards a center side of the inflow opening **41***a* by means of the plurality of the guide pieces **50**. For this reason, the compressed air A from the inflow opening **41***a* collides at the center portion of the inflow passage **41**, resulting in a considerable turbulent flow. As a result thereof, mixing the compressed air A with the fuel F may be facilitated. The premixed air-fuel mixture M**1** obtained in this manner described above collides against the center projection **54***a* and is therefore smoothly deflected by 90° before it is introduced into the inner premixing passage **43**.

[0043] As shown in FIG. **3**C, the mixing facilitation member **46** referred to previously is of a structure in which an insertion hole **46***a* for receiving therein the center tube P**1** of the flame holding fuel passage **48** is defined at a center portion thereof and a peripheral portion of the mixing facilitation member **46** has a plurality of, for example, four, radial projections **46***b* spaced an equal distance from each other in a direction circumferentially thereof. This mixing facilitation member **46** may be made of, for example, a metallic plate by the use of any suitable punching work. This mixture promoting member **46**, when fixed to the center tube P**1** at the insertion hole **46***a* thereof, is positioned upstream side of the speed increasing portion **45** in the premixing passage **43** and spaces **46***c* each delimited between the circumferentially neighboring projections **46***b* define respective flow paths for the premixed air-fuel mixture M**2**.

[0044] Referring now to FIG. **3**D, the plurality of, for example, twelve, first premixed air-fuel mixture injection holes **44**A, which are provided in the peripheral wall of the cylindrical body **20***a*. Each of those first premixed air-fuel mixture injection holes **44**A is so shaped as to be oriented in a direction slantwise radially outwardly, as shown in FIG. **3**A. Accordingly, a portion of the premixed air-fuel mixture Ml injected from the premixed air-fuel mixture injection holes **44**A flows towards the ignition plug **30** (shown in FIG. **2**).

[0045] FIG. **4** illustrates the pilot burner **20** as viewed from a downstream side. As shown therein, the pilot burner **20** has a tip end portion formed with the fuel injection hole **49** at a center portion which coincides with the axis C**1** of the pilot burner **20**, and the plurality of, for example, eight, second premixed air-fuel mixture injection holes **44**B are provided around the fuel injection hole **49**. On a radially outer side of the fuel injection hole **49** and a radially inner side of the circle depicted by the second premixed air-fuel mixture injection holes **44**B, a plurality of, for example, three, carbon removal injection holes **53** for supplying the premixed air-fuel mixture are provided. Those carbon removal injection holes **53** are so formed as to be inclined inwardly so that as shown in FIG. **3**A a portion of the premixed air-fuel mixture M**1** within the premixing passage **43** may be injected towards a tip end of the fuel injection hole **49**. Each of the carbon removal injection holes **53** is so formed as to have an extremely small diameter that is comparable with that of the fuel injection hole **49**.

[0046] Referring again to FIG. **3**A, a portion of the downstream end of the cylindrical body **20***a* of the pilot burner **20** is supported by the main inner peripheral wall **21***a* through an annular collar **57** of an L-sectioned configuration in a thermally deformable fashion.

[0047] The supplemental burner **40** has a structure substantially identical with that of the pilot burner **20** so far as a fuel injecting portion, which is positioned in an upstream area thereof, is concerned, and, therefore, the details thereof are not reiterated for the sake of brevity.

[0048] The operation of the pilot burner **20** employed in the gas turbine combustor according to the foregoing embodiment will now be described. In an entire range of load conditions of the gas turbine GT, the fuel F supplied from the fuel supply device **5** through the fuel control device **6** shown in FIG. **1** is introduced from the fuel introduction port **28**, shown in FIG. **3**A, into the pilot burner **20**. A portion of the fuel F so introduced is guided by the fuel introduction passage **48** and is then injected from the fuel injection hole **49** into the combustion chamber **11** shown in FIG. **2** for flame holding purpose. With the enriched fuel F injected from the fuel injection hole **49** and then undergoing a diffusion combustion, the flame stability and the ignitability may be improved. Considering that the amount of the fuel F injected from the fuel injection hole **49** is very small, the premix combustion accomplished by the pilot burner **20** is not adversely affected.

[0049] A major portion of the fuel F is introduced from the fuel supply holes **42** into the inflow passage **41**. Simultaneously therewith, the compressed air A from the compressor (shown in FIG. **1**) is introduced into the inflow passage **41** in a radially inward direction from the radially outer area through guide gaps each delimited between the neighboring guide pieces **50** and **50**. Under this condition, the compressed air A and the fuel F are mixed crosswise and, therefore, the compressed air A and the fuel F are guided axially towards a downstream side through the inner premixing passage **43** while the mixing of the compressed air A and the fuel F is facilitated by a shearing force brought about by the compressed air A relative to the fuel F. As hereinbefore described, the compressed air A and the fuel F flow radially inwardly within the inflow passage **41** to collide each other, accompanied by the enhanced turbulent flow enough to facilitate the mixing. In addition, the air-fuel mixture M**1** is deflected by 90° when the air-fuel mixture M**1** is guided from the inflow passage **41** into the premixing passage **43**, a considerable turbulence occurs in the flow and, hence, the premixing is facilitated. In addition, since the premixed air-fuel mixture M**1** is guided axially in a downstream direction through the premixing passage **43** that has a substantial length, the premixing is facilitated within this premixing passage **43**. The premixed air-fuel mixture M**1** referred to above is injected into the combustion chamber **11** from the plurality of premixing air-fuel mixture injection holes **44**A and **44**B and, therefore, uneven distribution of the premixed air-fuel mixture within the combustion chamber **11** is suppressed.

[0050] Since the premixed air-fuel mixture M**2** guided axially towards a downstream direction through the premixing passage **43** is deflected by the mixing facilitation member **46** radially outwardly, the turbulence becomes considerable and the premixing may be hence facilitated further. Also, since the mixing facilitation member **46** is provided in a portion of the premixing passage **43** upstream side of the speed increasing portion **45**, where the passage section is larger, and, hence, the flow velocity there is not high, an undesirable increase of the flow resistance brought about by the mixing facilitation member **46** may be suppressed.

[0051] Subsequently, the premixed air-fuel mixture M**2**, which has passed through the mixing facilitation member **46**, flows through the speed increasing portion **45** of a type having its passage section gradually decreasing in a downstream direction, accompanied by an increase of the flow velocity of the premixed air-fuel mixture M**2**. Therefore, an undesirable propagation of a back fire from the combustion chamber **11** (shown in FIG. **2**) towards the premixing passage **43** may be avoided. With the back firing prevented in this way, damage to the pilot burner **20** may be avoided accordingly.

[0052] A portion of the premixed air-fuel mixture M**1**, which has passed through the speed increasing portion **45**, is injected from the first premixed air-fuel mixture injection holes **44**A in a slantwise radially outward direction. Another portion of this premixed air-fuel mixture M**1** is injected from the second premixed air-fuel mixture injection holes **44**B into the combustion chamber **11** (shown in FIG. **2**), substantially outwards the axis C**1**. Also, the remaining portion of the premixed air-fuel mixture M**1** is injected from the carbon removal injection hole **53** in a slantwise direction towards the tip end of the fuel injection hole **49** to thereby lower the fuel concentration in the vicinity of an outlet of the fuel injection hole **49**. By so doing, an undesirable clogging of the fuel injection hole **49**, which would be brought about by soot resulting from an excessive enrichment of the fuel, may be prevented.

[0053] As hereinabove described, according to the pilot burner **20** according to the embodiment of the present invention, the compressed air A and the fuel F may be sufficiently mixed together and, therefore, the pilot premixed air-fuel mixture M**1** of a uniform concentration may be obtained. During the normal operation condition excluding the start-up and low load operating conditions, the main premixed air-fuel mixture M**2** is also supplied from the main burner **21**, shown in FIG. **2**, into the combustion chamber **11**. A first combustion region, which the premixed air-fuel mixture M**1** and the premixed air-fuel mixture M**2** in this case form, is indicated by S**1**. In addition, the supplemental burner **40** is also of a premixing type and, even from this supplemental burner **40**, an auxiliary firing premixed air-fuel mixture M**3** is supplied into and combusted within the combustion chamber **11**. A second combustion region in this case is indicated by S**2**. Because the supplemental burner **40** is also of the premixing type, generation of NOx in the second combustion region S**2** is suppressed and the emissions thereof may be reduced. Thus, since all of the pilot burner **20**, the main burner **21** and the supplemental burner **40** are of the premixing type, the amount of NOx may be considerably reduced as compared with a diffusion type which tends to be of a high temperature during the combustion and generates a substantial amount of NOx.

[0054] In contrast thereto, a conventional pilot burner **70** shown in FIG. **5**, is of a diffusion combustion type. The fuel F introduced from the fuel introduction port **28** is guided into the introducing passage **72**, then injected from a fuel injection hole **74** at a tip end and finally mixed with the compressed air A at an area outwardly downstream of the pilot burner **70**. Accordingly on a downstream side of the pilot burner **70**, the mixing of the compressed air A and the fuel F is insufficient and only an air-fuel mixture of a varying concentration can be obtained. Because of this, the combustion temperature tends to elevate, thus rendering the NOx to be easily formed.

[0055] Hereinafter, results of engine tests conducted on an engine equipped with the combustor, designed in accordance with the foregoing embodiment, and the conventional combustor of the structure shown in FIG. **5** will be discussed with particular reference to FIG. **6**. In the chart shown in FIG. **6**, the axis of abscissas represents the load factor relative to 100% taken as rated and the axis of ordinates represents the NOx concentration (the oxygen concentration in the air for combustion being 15%) measured at an outlet of the combustion liner. Comparative examples (a) and (b) shown in FIG. **6** represent respective curves descriptive of the results of tests conducted on engines equipped with the conventional DLE combustors. The pilot burner is of the diffusion type shown and referred to in FIG. **5** and the main burner and the supplemental burner are of a premixing type. In the comparative example (a), the supplemental burner was not operated, but at black triangle markings in the comparative example (b) the supplemental burner was operated. First and second examples represent the results of tests conducted on the engines mounted with the combustor according to the foregoing embodiment. In this instance, all of the pilot burner, the main burner and the supplemental burner are of the premixing type and, in the first example, the supplemental burner was not operated, but at black round marking in the second example, the supplemental burner was operated.

[0056] As the chart shown in FIG. **6** makes it clear, in the comparative example (a), the NOx concentration has increased considerably with an increase of the load factor. In the comparative example (b), by a quantity that the supplemental burner of the premixing type has been operated when comparing with the comparative example (a), the NOx concentration has markedly decreased in the region in which the load factor is high. In the first example of the present invention, due to the use of the pilot burner of the premixing type, the NOx concentration has decreased much smaller than that in the comparative example (a) as indicated by the downward oriented arrow Y**1**. Also, in the second example of the present invention, owning to the operation of the supplemental burner of the premixing type, the lowering of the NOx emission in a quantity greater than that in the comparative example (b) as indicated by the arrow Y**2** has been accomplished even within a region in which the load factor is high.

[0057] Although the present invention has been fully described in connection with the embodiments thereof with reference to the accompanying drawings which are used only for the purpose of illustration, those skilled in the art will readily conceive numerous changes and modifications within the framework of obviousness upon the reading of the specification herein presented of the present invention. Accordingly, such changes and modifications are, unless they depart from the scope of the present invention as delivered from the claims annexed hereto, to be construed as included therein.

REFERENCE NUMERALS

[0058] **1** . . . Compressor
[0059] **2** . . . Combustor
[0060] **3** . . . Turbine
[0061] **10** . . . Combustion liner
[0062] **11** . . . Combustion chamber
[0063] **15** . . . Air passage
[0064] **20** . . . Pilot burner
[0065] **21** . . . Main burner
[0066] **40** . . . Supplemental burner
[0067] **41** . . . Inflow passage
[0068] **41***a* . . . Inflow opening
[0069] **42** . . . Fuel supply hole
[0070] **43** . . . Premixing passage
[0071] **44**A, **44**B . . . Premixed air-fuel mixture injection hole
[0072] **45** . . . Speed increasing portion
[0073] **46** . . . Mixing facilitation member
[0074] **48** . . . Flame holding fuel passage
[0075] **49** . . . Fuel injection hole
[0076] **50** . . . Guide piece
[0077] **53** . . . Carbon removal injection hole
[0078] **54***a* . . . Center projection
[0079] A . . . Compressed air
[0080] F . . . Fuel
[0081] H . . . Housing
[0082] M**1** . . . Premixed air-fuel mixture

What is claimed is:

1. A gas turbine combustor to mix a compressed air, fed from a compressor, with a fuel to burn a resultant air-fuel mixture to be supplied to a turbine, which combustor comprising:
- a pilot burner provided in a top portion of a combustion liner defining a combustion chamber therein,
- a main burner of a premixing type located on an outer periphery side thereof, the pilot burner including:
  - an inflow passage provided in an upstream end portion to allow the compressed air to inflow from a radially outer area into a radially inner area;
  - a plurality of fuel supply holes to inject the fuel into the inflow passage in a direction perpendicular to the flow of the compressed air;
  - a premixing passage to mix the compressed air and the fuel inflowed through the inflow passage and to guide the air-fuel mixture towards an axially downstream side; and
  - a plurality of premixed air-fuel mixture injection holes to inject the premixed air-fuel mixture from the premixing passage into the combustion chamber.

2. The gas turbine combustor as claimed in claim **1**, further comprising a fuel injection hole formed at a center portion of the pilot burner to inject a portion of a fuel for the pilot burner into the combustion chamber.

3. The gas turbine combustor as claimed in claim **2**, further comprising a carbon removal injection hole formed in the vicinity of a downstream side of the fuel injection hole to supply a portion of the premixed air-fuel mixture within the premixing passage.

4. The gas turbine combustor as claimed in claim **1**, wherein the premixing passage includes a speed increasing portion having a passage section that gradually reduces towards a downstream side.

5. The gas turbine combustor as claimed in claim **4**, further comprising a mixing facilitation member provided on an upstream side of the speed increasing portion in the premixing passage to facilitate a premixing by deflecting the premixed air-fuel mixture radially outwardly.

6. The gas turbine combustor as claimed in claim **1**, wherein the inflow passage has an annular inflow opening, the inflow passage including a plurality of guide pieces positioned radially inwardly of the annular inflow opening to guide the compressed air towards a center of the inflow passage.

7. The gas turbine combustor as claimed in claim **6**, wherein the fuel supply holes are arranged at portions between the neighboring guide pieces.

8. The gas turbine combustor as claimed in claim **1**, wherein the plurality of premixed air-fuel mixture injection holes include a plurality of first air-fuel mixture injection holes provided in a peripheral wall of a cylindrical body that forms an outer wall of the premixing passage and a plurality of second air-fuel mixture injection holes provided in a tip end portion of the pilot burner.

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