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(54) **GAS TURBINE COMBUSTOR**

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(57) **ABSTRACT**

To suppress occurrence of combustion oscillation in a lean-combustion gas turbine combustor, and to improve the structural reliability. In a gas turbine combustor including: a tubular liner that forms a combustion chamber; and a burner having an air hole plate that is arranged at an inlet of the liner and that is provided with a plurality of air holes for guiding compressed air to the combustion chamber, and a plurality of fuel nozzles arranged on a side opposite to the combustion chamber with the air hole plate being sandwiched therebetween, the plurality of fuel nozzles each injecting a fuel toward a corresponding air hole, the air holes and the fuel nozzles forming a plurality of concentric annular lines, an orifice is provided on a fuel flow passage of each of the plurality of fuel nozzles, the plurality of fuel nozzles are grouped into a plurality of nozzle groups, and axial positions of the orifices are different between the nozzle groups.

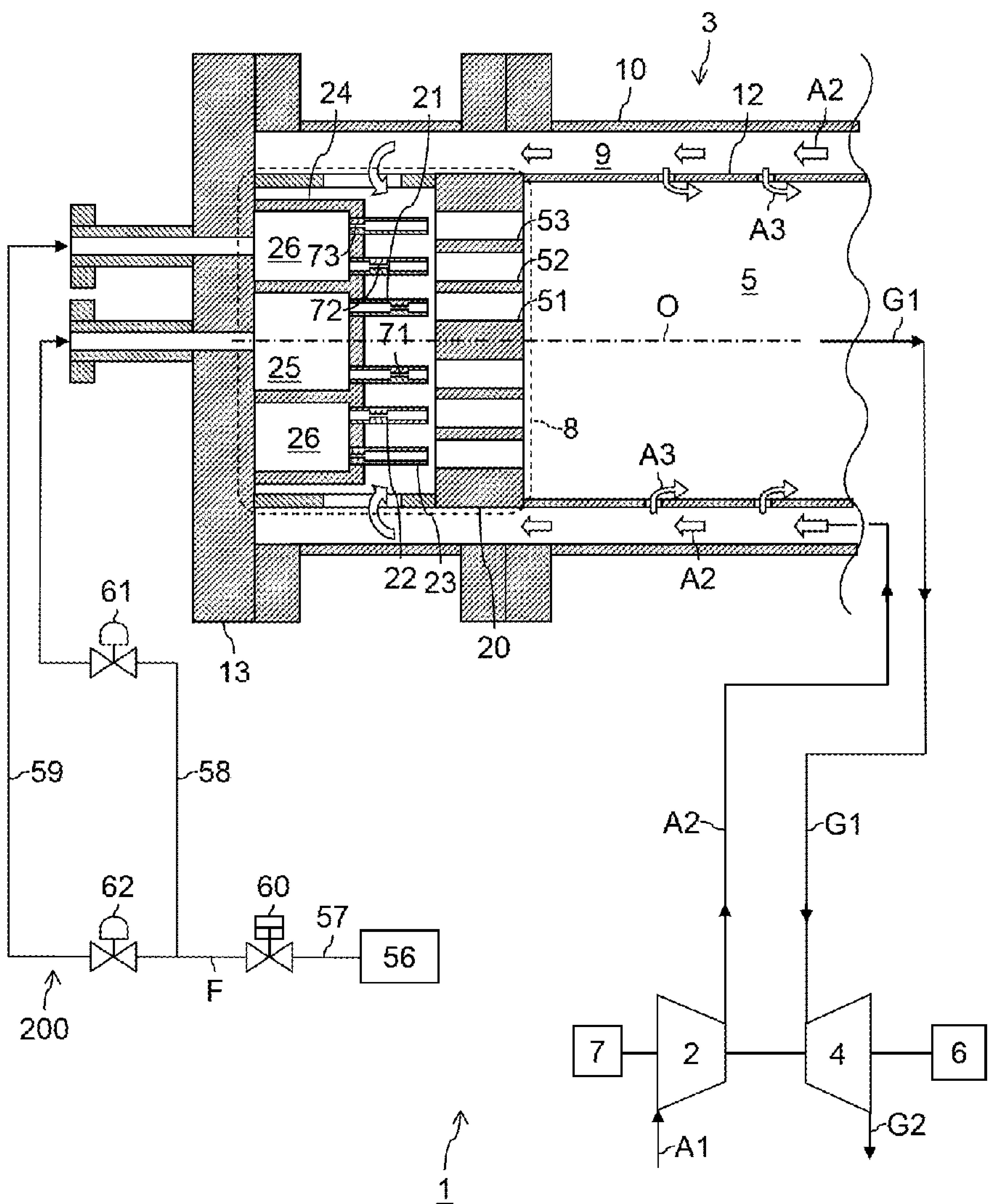


FIG.1

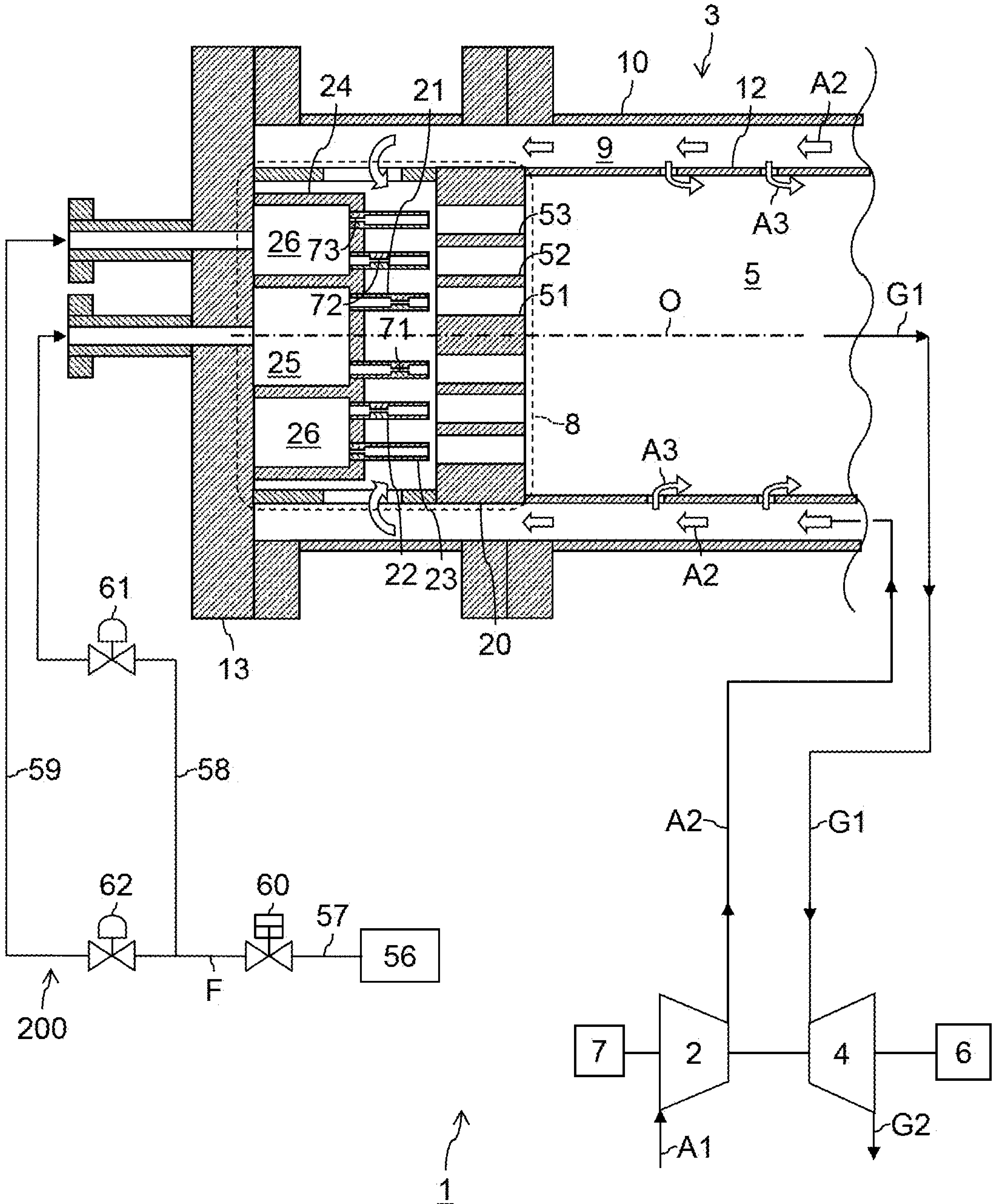

3
10
24
21
12
A2
9
A3
26
73
53
52
5
72
51
O
G1
71
25
26
8
A3
22
23
A2
61
13
20
59
58
A2
G1
62
60
57
56
F
200
7
2
4
6
G2
A1
1

FIG.2

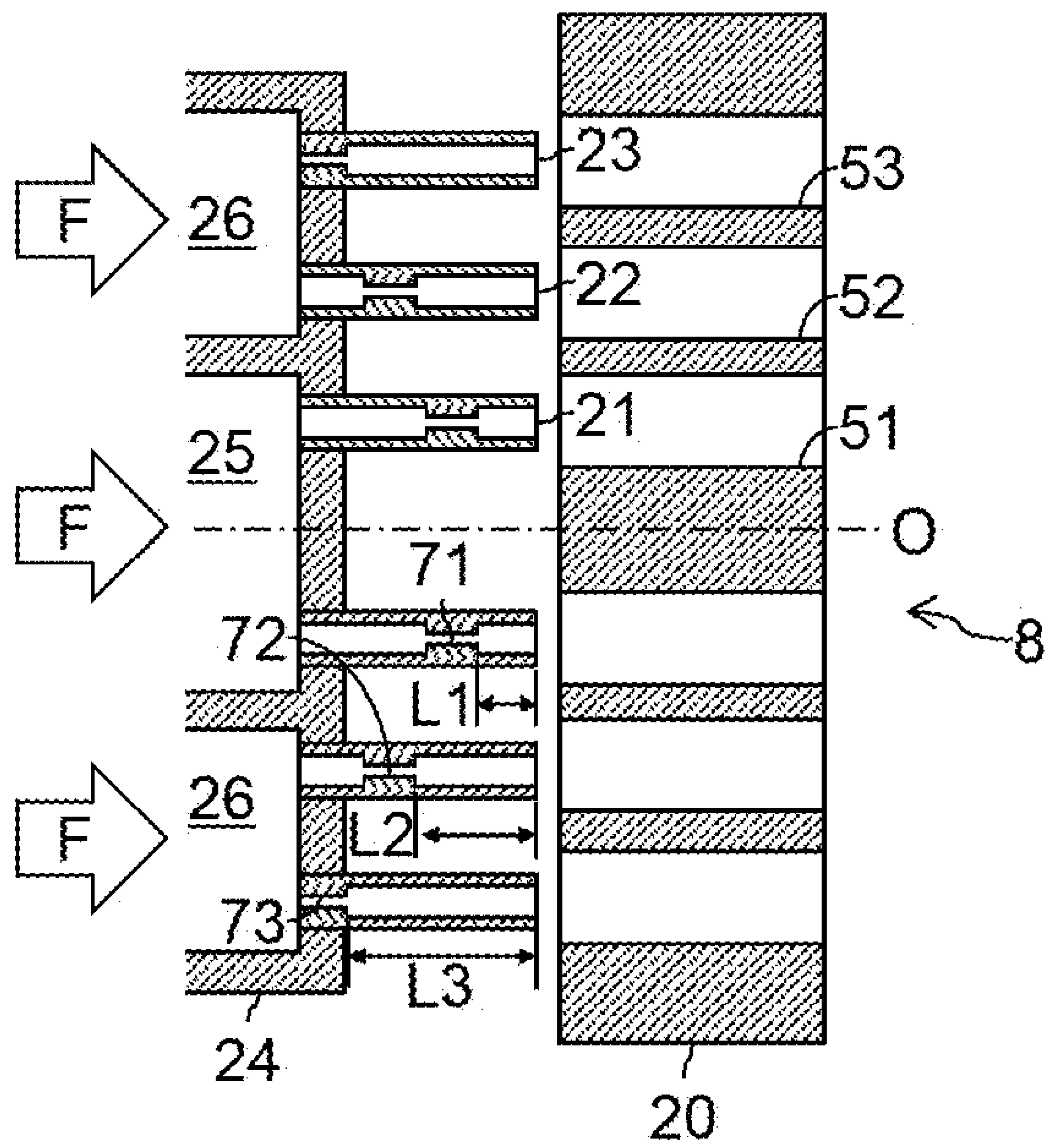


FIG.3

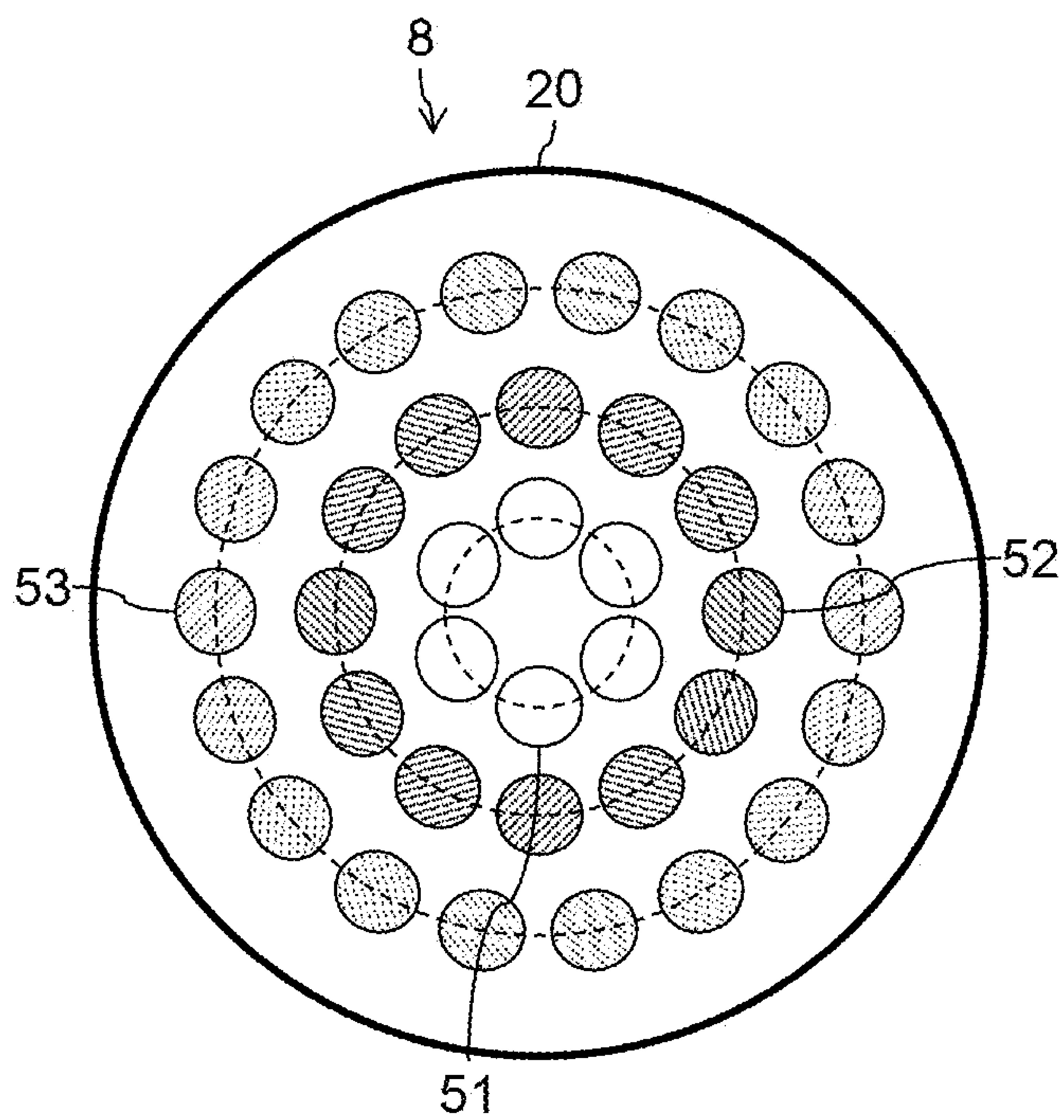


FIG.4

PRIOR ART

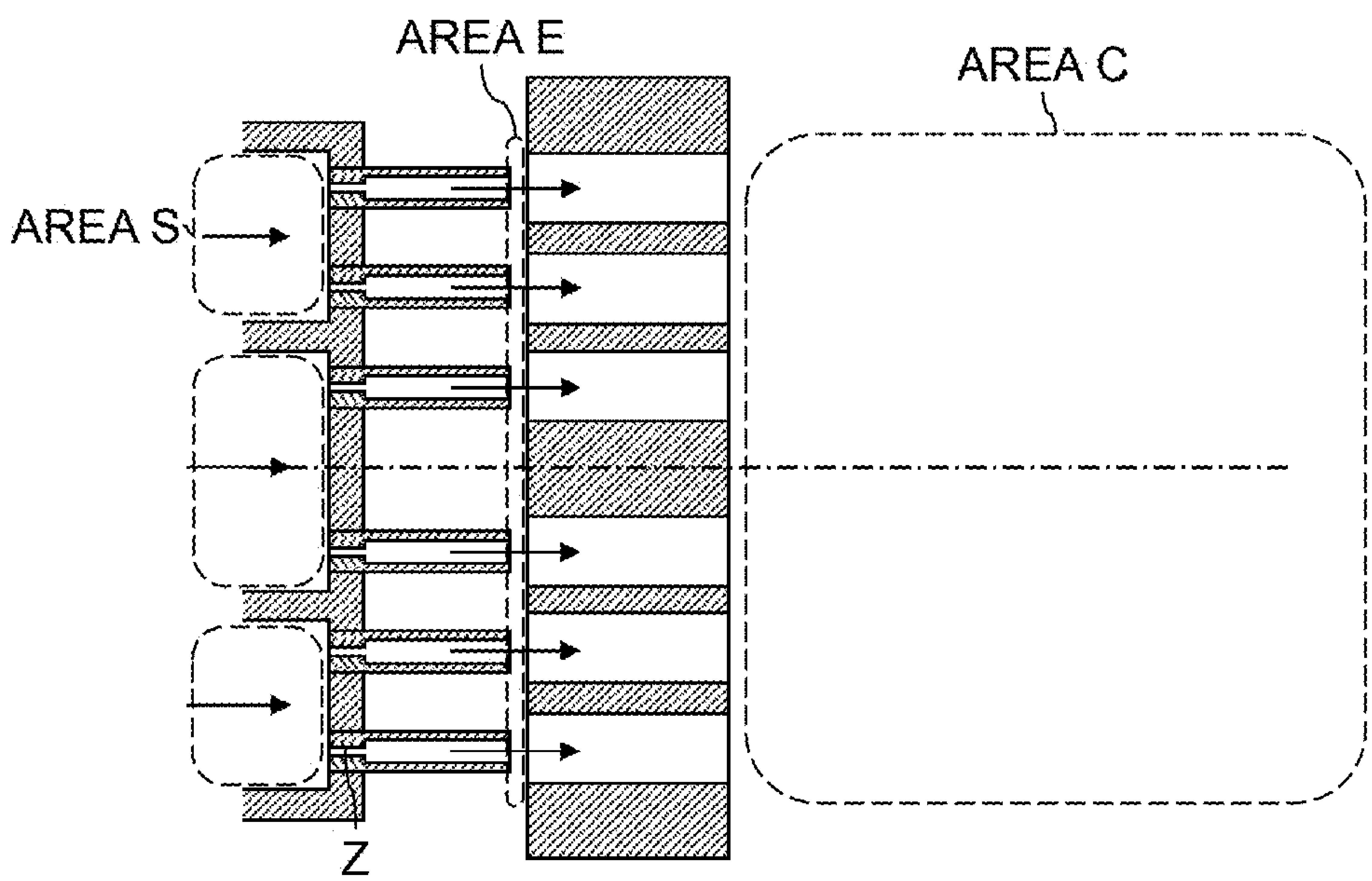


Fig. 5A
Fig. 5B
Fig. 5C
Fig. 5D
Fig. 5E
Fig. 5F

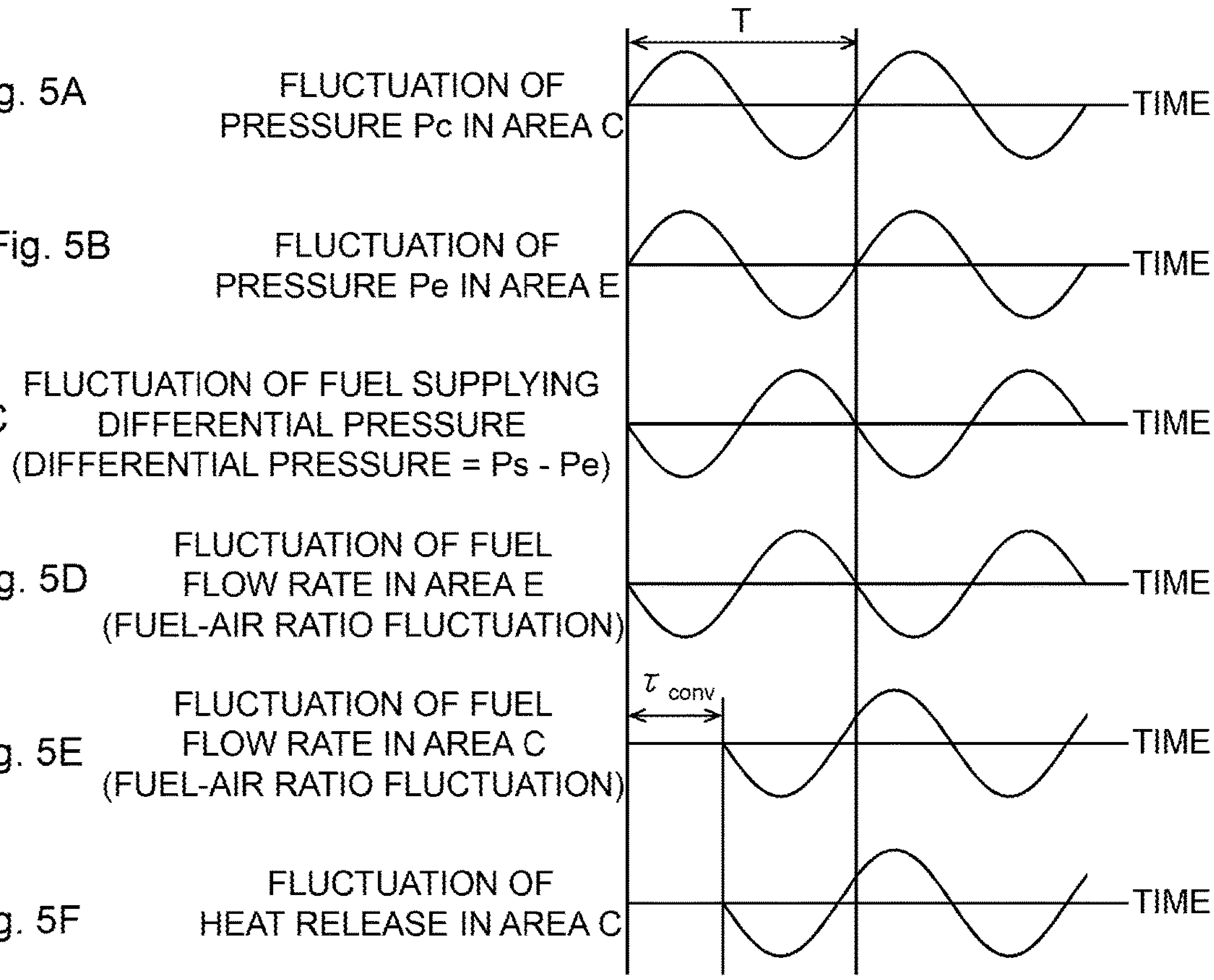


FIG.6

PRIOR ART

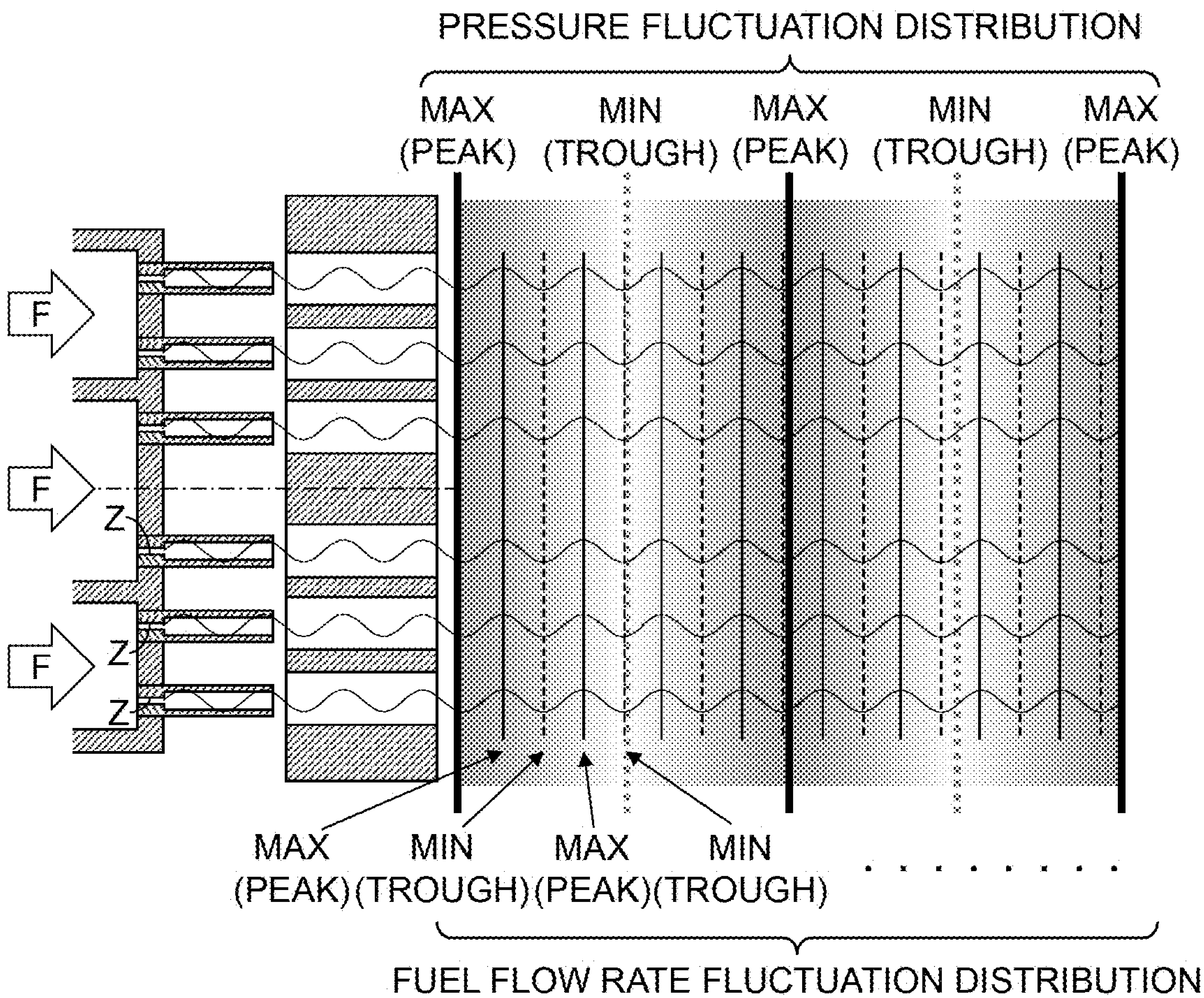


FIG.7

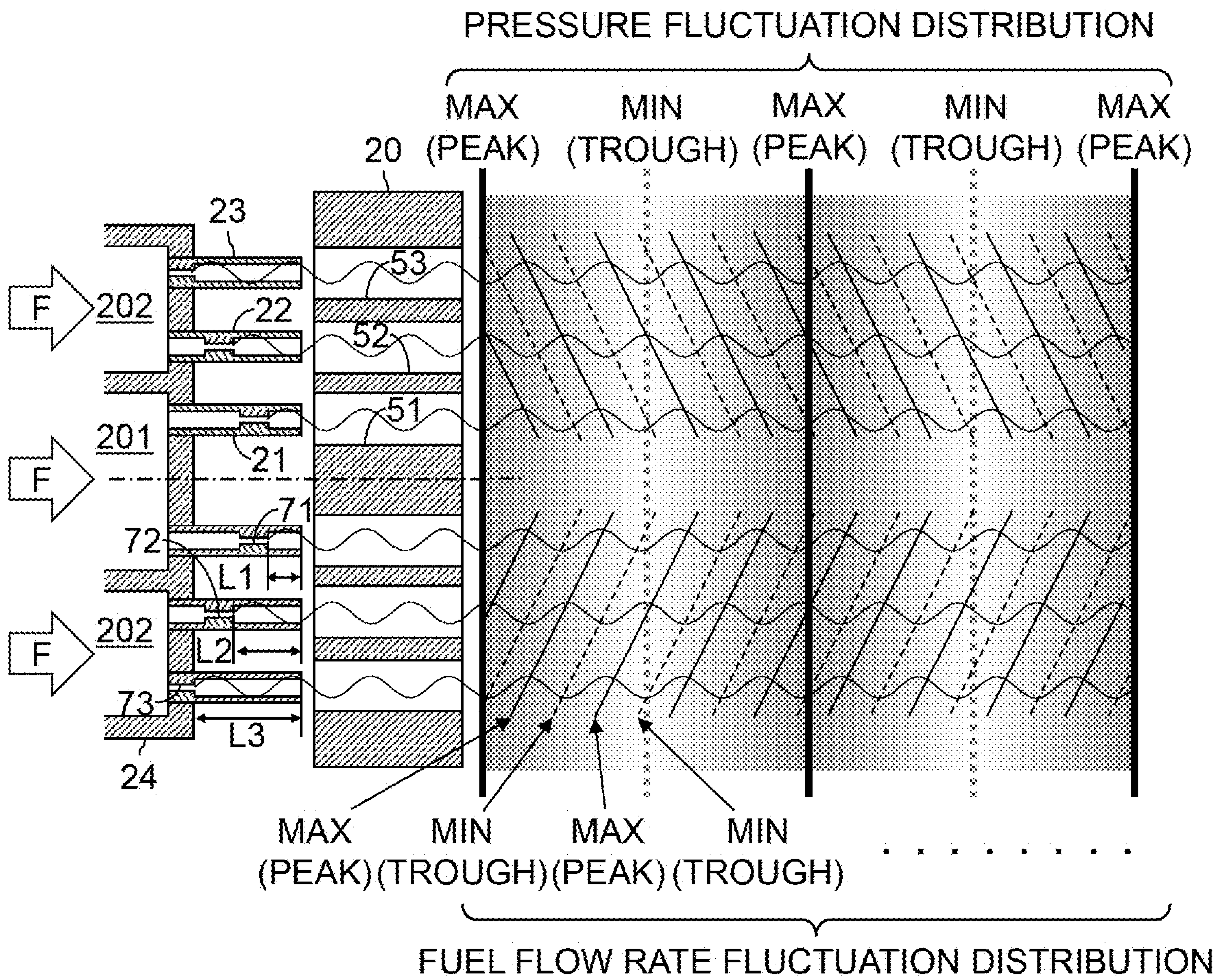

PRESSURE FLUCTUATION DISTRIBUTION
MAX (PEAK)
MIN (TROUGH)
MAX (PEAK)
MIN (TROUGH)
MAX (PEAK)
20
23
53
F
202
22
52
51
201
21
F
71
72
L1
202
F
L2
73
L3
24
MAX (PEAK)
MIN (TROUGH)
MAX (PEAK)
MIN (TROUGH)
FUEL FLOW RATE FLUCTUATION DISTRIBUTION

FIG.8

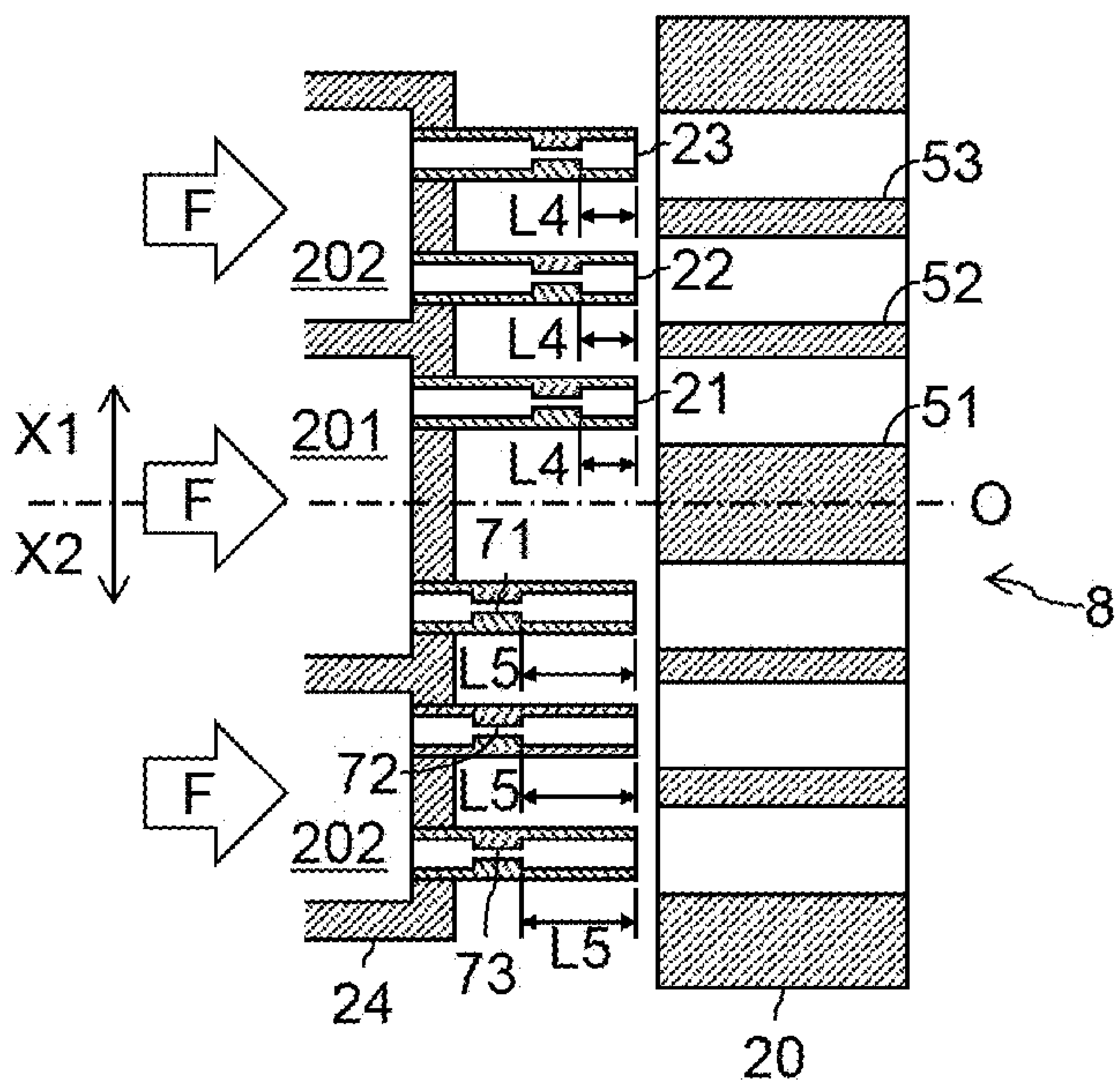

23
53
F
L4
202
22
52
L4
21
X1
201
51
L4
F
O
X2
71
8
L5
72
F
L5
202
73
L5
24
20

FIG.9

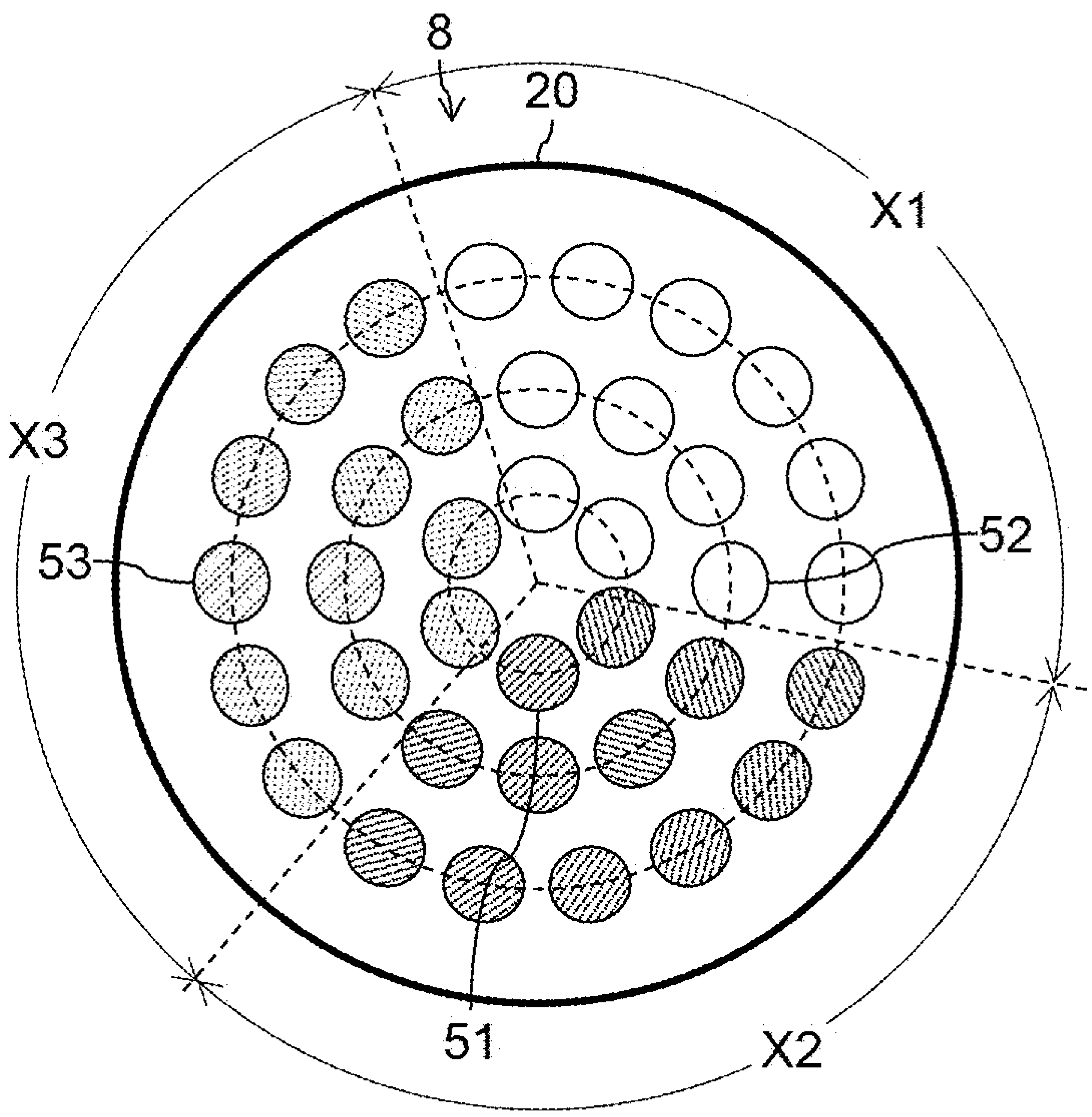

8
20
X1
X3
52
53
51
X2

FIG.10

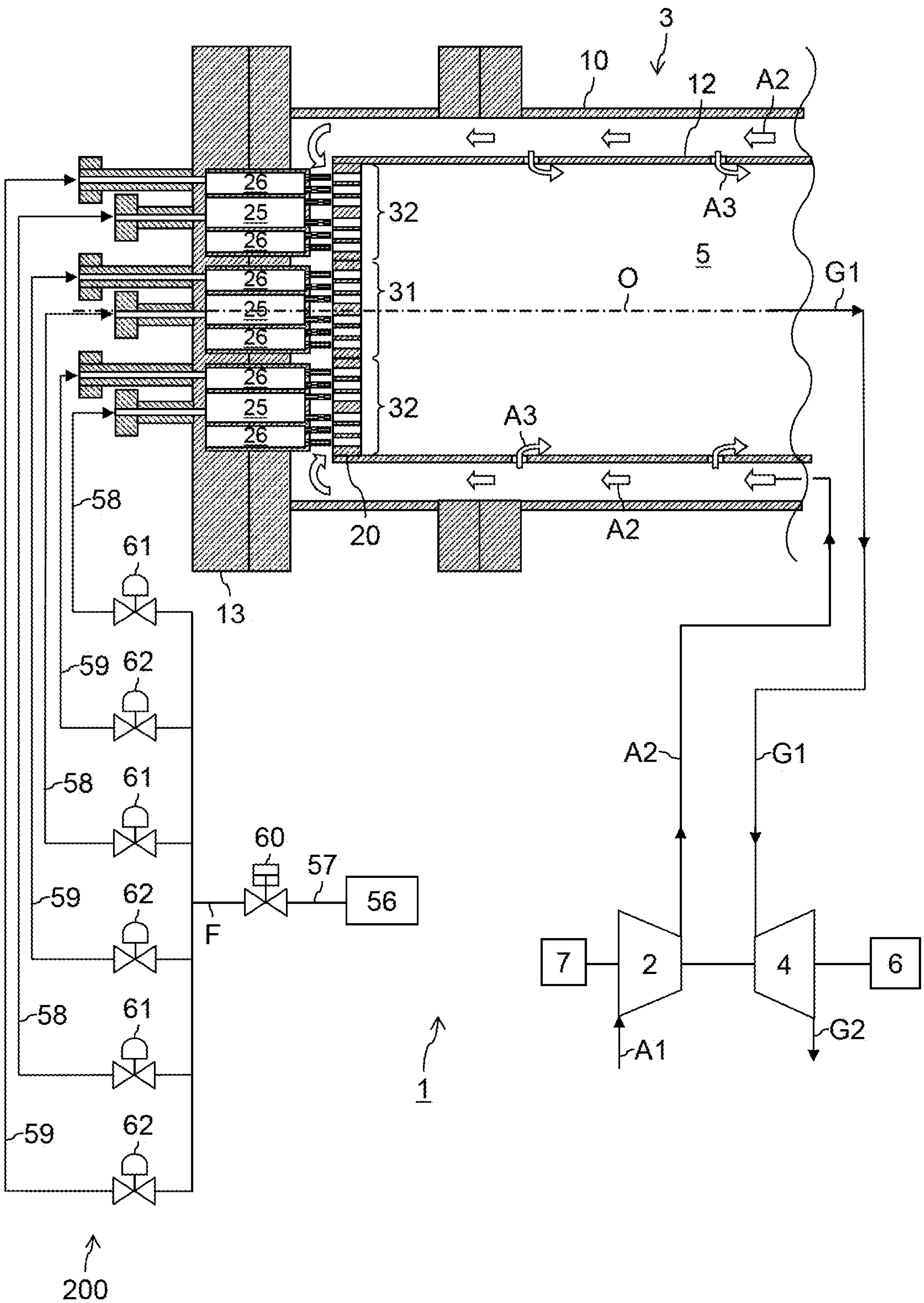
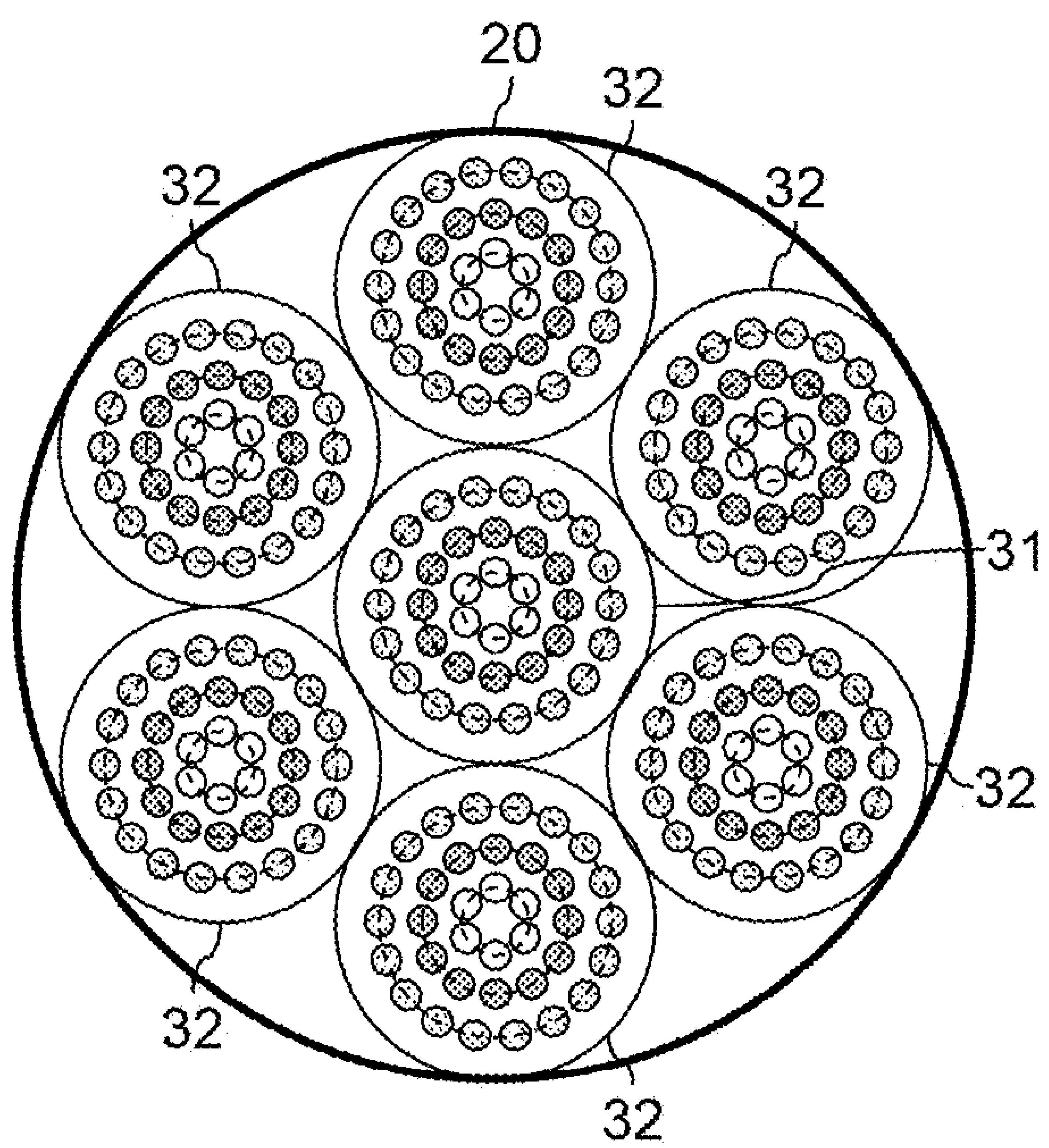

3
10
12
A2
26
25
26
32
A3
5
26
25
26
31
O
G1
26
25
26
32
A3
58
20
A2
61
13
59
62
58
61
A2
G1
60
57
59
62
56
F
7
2
4
6
58
61
G2
A1
1
59
62
200

FIG.11



GAS TURBINE COMBUSTOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a gas turbine combustor.

2. Description of the Related Art

[0002] At thermal power plants, it is demanded to improve power generation efficiency for reducing emissions of carbon dioxide (CO_2), which are a cause of global warming. An effective measure for improvement of the power generation efficiency of a gas turbine power plant is heating up combustion gas generated at a gas turbine combustor to a high temperature. However, heating up the combustion gas to a high temperature is accompanied by a technical problem related to suppression of emissions of nitrogen oxides (NOx) as a pollutant.

[0003] Typically, combustion methods of gas turbine combustors are roughly classified into diffusion combustion and premixed combustion.

[0004] In the diffusion combustion, fuel is directly injected into a combustion chamber and then mixed with air in the combustion chamber. Therefore, a flashback toward the upstream of the combustion chamber, and autoignition in fuel supply flow passages are less likely occur. Thus, the diffusion combustion provides good combustion stability. On the other hand, in the diffusion combustion, since flames are formed in areas where air is mixed with fuel in a ratio required for complete combustion of the fuel (stoichiometric mixing ratio), high temperature flames are locally generated. Because a large amount of NOx is generated in the local high temperature areas, it is necessary to reduce NOx emissions by injecting an inert medium such as water, steam or nitrogen. This necessitates power for an auxiliary machine that supplies the inert medium, leading to deterioration of the power generation efficiency.

[0005] In the premixed combustion, fuel and air are premixed with each other and then supplied to a combustion chamber, and NOx emissions are small because the fuel can be combusted in a lean mixture. On the other hand, in heating up the combustion gas to a high temperature, if the combustion air temperature is raised and the fuel concentration in a premixer is increased, the risk of flashback toward the upstream of the combustion chamber increases. This generates concern about damages caused by backfire to the structure of the combustor.

[0006] In view of this, there is a known lean-combustion combustor aimed for NOx emission reduction and flashback prevention by enhancing fuel dispersion and preventing local formation of high temperature flame (Patent Document 1, etc.). The lean-combustion combustor includes, for example, an air hole plate having a plurality of air holes and a plurality of fuel nozzles, and a fuel is injected from each fuel nozzle toward a corresponding air hole, and coaxial jets including a fuel flow and an air flow surrounding the fuel flow are supplied to a combustion chamber. This type of combustor includes one having a configuration in which orifices are installed at intermediate portions of fuel flow passages in fuel nozzles for control of the fuel flow rate, and reduction in deviation (Patent Document 2).

CITATION LIST

Patent Documents

[0007] Patent Document 1: JP-2003-148734-A

[0008] Patent Document 2: JP-2016-035336-A

[0009] There are a problem in lean-combustion combustors described in Patent Documents 1 and 2 in terms of suppression of combustion oscillation. Combustion oscillation is a type of resonance that occurs because of interference between the fluctuation of heat release by flames and the fluctuation of pressure in a combustion chamber. An occurrence of this combustion oscillation is sometimes accompanied by an occurrence of large amplitude pressure fluctuation at a particular frequency, and this generates concern about occurrence of cracks and damages in a gas turbine structure to deteriorate the structural reliability.

[0010] An object of the present invention is to provide a lean-combustion gas turbine combustor that can suppress occurrence of combustion oscillation, and improve the structural reliability.

SUMMARY OF THE INVENTION

[0011] In order to achieve the object described above, the present invention provides a gas turbine combustor including: a tubular liner that forms a combustion chamber; and a burner having an air hole plate that is arranged at an inlet of the liner and that is provided with a plurality of air holes for guiding compressed air to the combustion chamber, and a plurality of fuel nozzles arranged on a side opposite to the combustion chamber with the air hole plate being sandwiched therebetween, the plurality of fuel nozzles each injecting a fuel toward a corresponding air hole, the air holes and the fuel nozzles forming a plurality of concentric annular lines. In the gas turbine combustor, the plurality of fuel nozzles each include an orifice on a fuel flow passage, and are grouped into a plurality of nozzle groups, and axial positions of the orifices are different between the nozzle groups.

[0012] According to the present invention, it is possible to suppress occurrence of combustion oscillation in a lean-combustion gas turbine combustor, and to improve the structural reliability.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** is a schematic configuration diagram of a gas turbine power plant including a gas turbine combustor according to a first embodiment of the present invention;

[0014] FIG. **2** is a cross-sectional view that represents the configuration of main sections of a burner provided to the gas turbine combustor according to the first embodiment of the present invention, and includes the central axis of the burner;

[0015] FIG. **3** is a figure of the burner provided to the gas turbine combustor according to the first embodiment of the present invention as seen from a combustion chamber;

[0016] FIG. **4** is a figure illustrating a conventional burner structure;

[0017] FIGS. **5**A to **5**F are figures for explaining the mechanism of occurrence of combustion oscillation;

[0018] FIG. **6** is a figure representing a pressure fluctuation distribution and a fuel flow rate fluctuation distribution in a combustion chamber of a conventional burner;

[0019] FIG. **7** is a figure representing a pressure fluctuation distribution and a fuel flow rate fluctuation distribution in the combustion chamber of the burner according to the first embodiment;

[0020] FIG. **8** is a cross-sectional view that represents the configuration of main sections of the burner provided to the gas turbine combustor according to the second embodiment of the present invention, and includes the central axis of the burner;

[0021] FIG. **9** is a figure of the burner provided to the gas turbine combustor according to the second embodiment of the present invention as seen from the combustion chamber;

[0022] FIG. **10** is a schematic configuration diagram of the gas turbine power plant including the gas turbine combustor according to a third embodiment of the present invention; and

[0023] FIG. **11** is a figure of the burner provided to the gas turbine combustor according to the third embodiment of the present invention as seen from the combustion chamber.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] In the following, embodiments of the present invention are explained by using the drawings.

First Embodiment

—Gas Turbine Power Plant—

[0025] FIG. **1** is a schematic configuration diagram of a gas turbine power plant including a gas turbine combustor according to a first embodiment of the present invention. FIG. **2** is a cross-sectional view that represents the configuration of main sections of a burner provided to the gas turbine combustor according to the first embodiment of the present invention, and includes the central axis of the burner. FIG. **3** is a figure of the burner provided to the gas turbine combustor according to the first embodiment of the present invention as seen from a combustion chamber.

[0026] A gas turbine power plant **1** includes an air compressor **2**, a gas turbine combustor (hereinafter, referred to as a combustor for short) **3**, a turbine **4** and a generator **6**. The air compressor **2** sucks and compresses air A**1**, and supplies compressed air A**2** to the combustor **3**. The combustor **3** mixes the compressed air A**2** with a gaseous fuel F, combusts the mixture, and generates a combustion gas G**1**. The turbine **4** is driven by the combustion gas G**1** generated at the combustor **3**, and the combustion gas G1 that has driven the turbine **4** is emitted as an exhaust gas G**2**. The generator **6** is driven by the rotational motive power of the turbine **4**, and generates power. Note that the gas turbine is driven by a startup motor **7** only at the beginning of startup.

—Gas Turbine Combustor—

[0027] The combustor **3** is attached to a casing (not illustrated) of the gas turbine, and includes a liner (inner cylinder) **12**, a flow sleeve (outer cylinder) **10**, a burner **8** and a fuel supplying system **200**. The liner **12** is a cylindrical member, and forms a combustion chamber **5** thereinside. The flow sleeve **10** is a cylindrical member having an internal diameter larger than the diameter of the liner **12**, and surrounds the outer circumference of the liner **12**. The flow sleeve **10** forms a cylindrical air flow passage **9** between itself and the liner **12**. An end section of the flow sleeve **10** on a side opposite to a side that the turbine **4** is located, i.e., the left side in FIG. **1**, is closed off by an end cover **13**. The compressed air A**2** from the air compressor **2** flows in a direction away from the turbine **4** through the air flow passage **9** formed on the outer circumference of the liner **12** by the flow sleeve **10**, thus convection cooling of the outer circumferential surface of the liner **12** is conducted by the compressed air A**2** flowing through the air flow passage **9**. Additionally, a large number of holes are formed through the wall surface of the liner **12**. A part A**3** of the compressed air A**2** flowing through the air flow passage **9** passes through those holes to flow into the combustion chamber **5**, and film-cools the inner circumferential surface of the liner **12**. Then, the compressed air A**2** having passed through the air flow passage **9** and reached the burner **8** is spouted out for combustion to the combustion chamber **5** together with the gaseous fuel F supplied from the fuel supplying system **200** to the burner **8**. In the combustion chamber **5**, the mixture of the compressed air A**2** and the gaseous fuel F is combusted to generate the combustion gas G**1**. The combustion gas G**1** is supplied to the turbine **4** via a combustor transition piece (not illustrated).

[0028] As illustrated in FIG. **1**, the only one burner **8** is arranged at the inlet of the liner **12**, i.e., at an opening at an end section on the side opposite to the side the turbine **4** is located, and includes an air hole plate **20**, fuel nozzles **21** to **23** and a fuel distributor (fuel header) **24**.

[0029] The air hole plate **20** is a circular plate coaxial with the liner **12**, and is arranged at the inlet of the liner **12**, i.e., at the opening at the end section on the side opposite to the side the turbine **4** is located. The air hole plate **20** includes a plurality of air holes **51** to **53** that guide the compressed air A**2** to the combustion chamber **5**. The plurality of air holes **51** to **53** form a plurality of concentric annular lines having their center on a central axis O of the liner **12**. The air holes **51** belong to the first (innermost) annular line, the air holes **52** belong to the second annular line, and the air holes **53** belong to the third (outermost) annular line. In the present embodiment, the air holes **51** to **53** are provided at swirl angles, and the outlet of each hole is shifted toward one side in the circumferential direction relative to the inlet of the hole.

[0030] The fuel nozzles **21** to **23** are supported by the fuel distributor **24**, and are arranged on a side opposite to the combustion chamber **5** with the air hole plate **20** being sandwiched therebetween. The numbers and positions of the fuel nozzles **21** to **23** correspond to the numbers and positions of the air holes **51** to **53** (one fuel nozzle corresponds to one air hole), and the fuel nozzles **21** to **23** form, together with the air holes **51** to **53**, a plurality of concentric annular lines having their center on the central axis O of the liner **12**. The fuel nozzles **21** belong to the first (innermost) annular line, the fuel nozzles **22** belong to the second annular line, and the fuel nozzles **23** belong to the third (outermost) annular line. The fuel nozzles **21** to **23** have injection ports opening toward the inlets of corresponding air holes, and inject the gaseous fuel F toward those corresponding air holes. By causing the fuel to be injected from a large number of fuel nozzles to corresponding air holes in this way, coaxial jets of the fuel and air, in which the circumference of a fuel flow is covered by an air flow, are injected dispersedly from each air hole to the combustion chamber **5**.

[0031] Note that due to differences in circumference between the annular lines, outer annular lines have larger numbers of fuel nozzles and air holes. That is, the numbers of the fuel nozzles **21** and air holes **51** in the first (innermost) line (the six fuel nozzles **21**, and the six air holes **51** in the example illustrated in FIG. **3**) are smaller than the numbers of the fuel nozzles **22** and air holes **52** in the second line (the twelve fuel nozzles **22**, and the twelve air holes **52** in the example illustrated in FIG. **3**). The numbers of the fuel nozzles **22** and air holes **52** in the second line are smaller than the numbers of the fuel nozzles **23** and air holes **53** in the third (outermost) line (the eighteen fuel nozzles **23**, and the eighteen air holes **53** in the example illustrated in FIG. **3**).

[0032] The fuel distributor **24** is a member that supplies the fuel separately to the fuel nozzles **21** to **23**, and includes a plurality of fuel cavities **25** and **26** thereinside. The fuel cavities **25** and **26** are spaces that play a role of supplying the gaseous fuel F separately to a plurality of fuel nozzles belonging to corresponding annular lines. The fuel cavity **25** is formed to have a columnar shape on the central axis O of the liner **12**, and the fuel cavity **26** is formed to have a cylindrical shape such that the fuel cavity **26** surrounds the outer circumference of the fuel cavity **25**. In the present embodiment, each of the fuel nozzles **21** is connected to the fuel cavity **25**, and each of the fuel nozzles **22** and **23** is connected to the fuel cavity **26**. The gaseous fuel F supplied to the fuel cavity **25** is distributed to each fuel nozzle **21** arranged in the innermost annular line and then spouted out, and the gaseous fuel F having been spouted out from the fuel nozzle **21** is spouted out together with the compressed air A**2** from each air hole **51** to the combustion chamber **5**. The gaseous fuel F supplied to the fuel cavity **26** is distributed to each of the fuel nozzle **22** and **23** arranged in the second and third annular line and then spouted out, and the gaseous fuel F having been spouted out from the fuel nozzle **22** and **23** is spouted out together with the compressed air A**2** from the air holes **52** and **53** to the combustion chamber **5**.

[0033] Here, in the present embodiment, the plurality of fuel nozzles **21** to **23** include orifices **71** to **73**, respectively, on their fuel flow passages. One fuel nozzle includes only one orifice. The fuel nozzles **21** to **23** (all the fuel nozzles) are grouped into a plurality of nozzle groups, and the axial positions of orifices are different between nozzle groups. In the present embodiment, fuel nozzles grouped into the same nozzle group belong to the same annular line. The fuel nozzles **21** in the innermost line belong a first nozzle group, the fuel nozzles **22** in the second line belong a second nozzle group, and the fuel nozzles **23** in the outermost line belong a third nozzle group. Then, an orifice **71** is provided to each fuel nozzle **21**, an orifice **72** is provided to each fuel nozzle **22**, and an orifice **73** is provided to each fuel nozzle **23**. Note that air holes represented without hatching in FIG. **3** (the air holes **51** in the present example) correspond to the orifices **71**. Air holes differently represented by hatching sloping upward to the right (the air holes **52** in the present example) correspond to the orifices **72**, and air holes differently represented by hatching sloping downward to the right (the air holes **53** in the present example) correspond to the orifices **73**.

[0034] The orifices **71** to **73** are different to each other in axial position. The distance L**2** from the outlets of the orifices **72** to the outlets (injection ports) of the fuel nozzles **22** is longer than the distance L**1** from the outlets of the orifices **71** to the outlets of the fuel nozzles **21**. The distance L**3** from the orifices **73** to the outlets of the fuel nozzles **23** is still longer than the distance L**2** (L**1**<L**2**<L**3**). The axial positions of the outlets of the fuel nozzles **21** to **23** are the same, and the orifices **71**, **72** and **73** are arranged in this order from the side of the combustion chamber **5**. In the present embodiment, the orifices **71** are at positions which are in the middle of the fuel nozzles **21** in the axial direction or are closer to the combustion chamber **5** than the middle, the orifices **73** are at inlet sections of the fuel nozzles **23**, and the orifices **72** are at intermediate axial positions between the orifices **71** and **73**. It should be noted, however, that the order from the combustion chamber **5** side can be changed. For example, the orifices **73**, **72** and **71** may be arranged in this order from the combustion chamber **5** side, and may be arranged in the order of the orifices **73**, **71** and **72** from the combustion chamber **5** side.

[0035] As described above, in the present embodiment, the axial positions of orifices of fuel nozzles belonging to the same annular line coincide with each other, and the fuel is to be supplied from the same fuel cavity to all the fuel nozzles having orifices at the same position. All the fuel nozzles **21** include the orifices **71** at the same position, and these fuel nozzles **21** receive a supply of the fuel from the same fuel cavity **25**. In addition, all the fuel nozzles **22** include the orifices **72** at the same position, and receive a supply of the fuel from the same fuel cavity **26**. All the fuel nozzles **23** include the orifices **73** at the same position, and receive a supply of the fuel from the fuel cavity **26**.

[0036] In addition, in the present embodiment, the opening diameters of the orifices **71** belonging to the innermost annular line are made larger than the opening diameters of the orifices **73** belonging to the outermost annular line. The opening diameters of the orifices **72** belonging to the second annular line can be set to opening diameters within the range from the opening diameters of the orifices **71** to the opening diameters of the orifices **73** inclusive, and are made equal to the opening diameters of the orifices **73** in the present embodiment. Note that the opening diameters of the outlets (injection ports) of the fuel nozzles **21** to **23** are larger than the opening diameters of the orifices **71** to **73** so as to avoid increase in pressure loss that may otherwise be caused by further narrowing the fuel flows having been narrowed at the orifices **71** to **73**.

[0037] The fuel supplying system **200** includes a fuel supplying source **56**, a main flow pipeline **57**, branch pipelines **58** and **59**, a fuel shut valve **60** and fuel flow control valves **61** and **62**. The main flow pipeline **57** extends from the fuel supplying source **56**, and the main flow pipeline **57** branches into the two branch pipelines **58** and **59**. The branch pipeline **58** is connected to the fuel cavity **25**, and the branch pipeline **59** is connected to the fuel cavity **26**. The fuel shut valve **60** is provided on the main flow pipeline **57**, the fuel flow control valve **61** is provided on the branch pipeline **58**, and the fuel flow control valve **62** is provided on the branch pipeline **59**. By opening the fuel shut valve **60**, the gaseous fuel F starts being supplied to the branch pipelines **58** and **59**, and by closing the fuel shut valve **60**, the supply of the gaseous fuel F to the branch pipelines **58** and **59** is shut off. The fuel flow control valves **61** and **62** play a role of controlling the flow rates of the fuel flowing through the branch pipelines **58** and **59** in accordance with their openings, and the flows of the fuel through the branch pipelines **58** and **59** can also be shut off by fully closing the fuel flow control valves **61** and **62**. For example, by opening the fuel shut valve **60**, and increasing the opening of the fuel flow control valve **61** from its fully closed state, the supply flow rate of the fuel to the fuel cavity **25** is increased, and the amount of fuel-injection from the fuel nozzles **21** is increased, which in turn increases the fuel-air ratio of coaxial jets being spouted out from the air holes **51**. Similarly, by increasing the opening of the fuel flow control valve **62** from its fully closed state, the supply flow rate of the fuel to the fuel cavity **26** is increased, and the amount of fuel-injection from the fuel nozzles **22** and **23** is increased, which in turn increases the fuel-air ratio of coaxial jets being spouted out from the air holes **52** and **53**.

[0038] Note that as the gaseous fuel F supplied from the fuel supplying source **56**, other than natural gas which is a typical gas turbine fuel, a petroleum gas or a gas containing hydrogen or carbon monoxide such as a coke oven gas, a refinery off-gas, or a coal-derived gas can be used.

—Principle of Occurrence of Combustion Oscillation—

[0039] A conventional burner structure is illustrated in FIG. **4**. For comparison, the figure illustrates a burner having a plurality of air holes and fuel nozzles arranged therein in three concentric annular lines as in the present embodiment, and the fuel nozzles in all the three lines have orifices Z that are uniformly installed therein at the same axial position.

[0040] FIGS. **5**A to **5**F are figures for explaining the mechanism of occurrence of combustion oscillation. The graphs of FIGS. **5**A to **5**F represent temporal changes in pressure, fuel supplying differential pressure, fuel flow rate and heat release that are observed near (an area E in FIG. **4**) the outlets of fuel nozzle tips of the burner or in a combustion chamber (an area C in FIG. **4**) on the downstream side of the burner. It has been found in recent years that interference between pressure fluctuation and fluctuation of heat release by flames in the combustion chamber causes combustion oscillation by a mechanism like the one illustrated by the following (a) to (f). The explanations of (a) to (f) correspond to FIGS. **5**A to **5**F, respectively.

[0041] (a) Fluctuation (the fluctuation period is defined as T) of the pressure Pc in a downstream area of the burner in the combustion chamber (the area C) occurs.

[0042] (b) Similar to (a), the pressure Pe near the outlets of the fuel nozzle tips (the area E) fluctuates in phase with the pressure Pc.

[0043] (c) Because the pressure Ps of the fuel in the fuel distributor (areas S in FIG. **4**) is constant, the fuel supplying differential pressure (Ps−Pe) fluctuates out of phase with the pressures Pc and Pe.

[0044] (d) The flow rate of the fuel having been spouted out from the fuel nozzles to the area E fluctuates in phase with the fuel supplying differential pressure (Ps−Pe), and the fuel-air ratio in the area E (the flow rate ratio of the fuel relative to air) also fluctuates in phase.

[0045] (e) The fuel flow rate in the area C fluctuates with a phase delay by the convection time τconv of the fuel from the area E to the area C with respect to the fuel flow rate fluctuation in the area E and the fuel-air ratio in the area C also fluctuates in the same phase.

[0046] (f) The mixture of the fuel and air is combusted and releases heat in the area C, and the heat release by flames fluctuates in phase with the fuel-air ratio.

[0047] The series of fluctuation in (a) to (f) above occurs, and the pressure fluctuation (in FIG. **5**A) and the heat release fluctuation (in FIG. **5**F) are in phase in the area C to intensify each another; as a result, combustion oscillation occurs.

[0048] FIG. **6** is a figure representing a pressure fluctuation distribution and a fuel flow rate fluctuation distribution in the combustion chamber of the conventional burner. In FIG. **6**, the pressure fluctuation distribution is represented by representing maxima/minima of the amplitude that fluctuates in the axial direction (peaks/troughs of the fluctuation amplitude) by shading. In addition, FIG. **6** represents the fuel flow rate fluctuation distribution by representing maxima/minima of the amplitude that fluctuates in the axial direction (peaks/troughs of the fluctuation amplitude) by sinusoidal waves. Planes passing through points of the same phases in the pressure fluctuation distribution in the combustion chamber become parallel to a burner surface (air hole plate). Then, because the orifices Z of the fuel nozzles in all the three lines are installed at the same axial position in the conventional burner, planes passing through points of the same phase in the flow rate fluctuation distribution of the fuel that is spouted out from the fuel nozzles also inevitably become parallel to the burner surface. This leads to increase in areas in the combustion chamber where the pressure fluctuation and the fuel flow rate fluctuation intensify each another due to the matching phases, and thus combustion oscillation is likely to occur in the entire area located downstream of the three lines of air holes.

—Effects—

[0049] (1) According to the present embodiment, because the axial positions of orifices are different between nozzle groups, occurrence of combustion oscillation can be suppressed even under a part load condition. The principle is explained below.

[0050] FIG. **7** is a figure representing a pressure fluctuation distribution and a fuel flow rate fluctuation distribution in the combustion chamber of the burner according to the first embodiment. Similar to FIG. **6**, FIG. **7** also illustrates peaks/troughs of the fluctuation amplitude in the pressure fluctuation distribution and the fuel flow rate fluctuation distribution by shading and sinusoidal waves, respectively. Planes passing through points of the same phases in the pressure fluctuation distribution in the combustion chamber become parallel to the burner surface in the present embodiment also, as in the conventional burner. In contrast, in the present embodiment, because the axial positions of orifices are made different between nozzle groups, planes passing through points of the same phase in the flow rate fluctuation distribution of the fuel that is spouted out from the fuel nozzles **21** to **23** are inclined with respect to the burner surface. This limits areas where the phases of the pressure fluctuation and the fuel flow rate fluctuation match with each other, and thus combustion oscillation less likely to occur in the entire area located downstream of the air holes **51** to **53**. Thereby, occurrence of combustion oscillation can be suppressed, and the structural reliability of the lean-combustion gas turbine combustor can be improved.

[0051] In addition, in the present embodiment, the fuel flows of the gaseous fuel F are injected separately from a large number of the fuel nozzles **21** to **23**, and each fuel flow is individually caused to pass through a corresponding one of the air holes **51** to **53**. Thereby, it is possible to cause each fuel flow to spout out to the combustion chamber **5** as coaxial jets surrounded by the compressed air A**2**. Thereby, the fuel dispersion can be enhanced to reduce NOx emissions.

[0052] (2) In a case where the gas turbine according to the present embodiment starts running, after the gaseous fuel F is supplied to the fuel nozzles **21** in the first (innermost) line, and ignited, the gaseous fuel F is supplied also to the fuel nozzles **22** and **23** in the second and third lines under a part load condition, and the load is raised to a base load condition. In a combustor that is ran in this way, specifications such as the lengths of fuel nozzles and opening diameters of the outlets (injection ports) of fuel nozzles are often decided for each annular line. Accordingly, by determining specifications of orifices also for each annular line, that is, by providing nozzles of identical specifications with identical orifices at the same positions, the number of types of fuel nozzles to be fabricated can be reduced, and this contributes to reduction in fabrication cost of fuel nozzles.

[0053] From this perspective, because the axial positions of orifices of fuel nozzles belonging to the same annular line coincide with each other in the present embodiment, the fabrication cost of fuel nozzles can be reduced, which in turn reduces the fabrication cost of the burner **8**, the combustor **3** and the gas turbine power plant.

[0054] (3) In the present embodiment, the opening diameters of the orifices **71** provided to the fuel nozzles **21** belonging to the innermost annular line are made larger than the opening diameters of the orifices **73** provided to the fuel nozzles **23** belonging to the outermost annular line. By making larger the opening diameters of orifices in inner annular lines including smaller numbers of fuel nozzles in this way, excessive increase in fuel supplying differential pressure can be suppressed.

[0055] It should be noted, however, that as long as the essential effect (1) mentioned before can be attained, it is not necessarily required to make the opening diameters of orifices different from one another, and in a possible configuration, the opening diameters of the orifices **71** to **73** coincide with each other.

Second Embodiment

—Configuration—

[0056] FIG. **8** is a cross-sectional view that represents the configuration of main sections of the burner provided to the gas turbine combustor according to the second embodiment of the present invention, and includes the central axis of the burner. FIG. **9** is a figure of the burner provided to the gas turbine combustor according to the second embodiment of the present invention as seen from the combustion chamber. These FIG. **8** and FIG. **9** correspond to FIG. **2** and FIG. **3** illustrating the first embodiment, respectively.

[0057] The present embodiment is different from the first embodiment in that annular lines are grouped into a plurality of areas X**1** to X**3** in the circumferential direction, nozzle groups are grouped in accordance with these areas X**1** to X**3**, and fuel nozzles having orifices at different axial positions are mixedly present in the same annular line. The orifices **71** to **73** belonging to the area X**1** are at the same axial position at a distance L**4** from the nozzle outlets, and the orifices **71** to **73** belonging to the area X**2** are at the same axial position at a distance L**5** (>L**4**) from the nozzle outlets. Although not illustrated in FIG. **8**, the orifices **71** to **73** belonging to the area X**3** are at the same axial position at a distance L**6** (>L**5**) from the nozzle outlets. The air holes **51** to **53** in the area X**1** represented without hatching in FIG. **9** correspond to the orifices **71** to **73** at the position at the distance L**4**. The air holes **51** to **53** in the area X**2** differently represented by hatching sloping upward to the right correspond to the orifices **71** to **73** at the position at the distance L**5**, and the air holes **51** to **53** in the area X**3** differently represented by hatching sloping downward to the right correspond to the orifices **71** to **73** at the position at the distance L**6**. In this manner, the fuel nozzles **21** having the orifices **71** at different axial positions are mixedly present in the first (innermost) annular line. Similarly, the fuel nozzles **22** having the orifices **72** at different axial positions are mixedly present in the second annular line, and the fuel nozzles **23** having the orifices **73** at different axial positions are mixedly present in the third (outermost) annular line.

[0058] Other aspects including the configurations of the fuel nozzles **21** to **23** and air holes **51** to **53**, only one orifice being provided to one fuel nozzle, and the opening diameters of the orifices **71** in an inner line being made large are similar to the first embodiment.

—Effects—

[0059] In the present embodiment, the following effects can be attained in addition to the effects described in (1) and (3) that are similar to the first embodiment. In a case where the gas turbine according to the present embodiment starts running, after the gaseous fuel F is supplied to the fuel nozzles **21** in the first (innermost) line, and ignited, the gaseous fuel F is supplied also to the fuel nozzles **22** and **23** in the second and third lines under a part load condition, and the load is raised to a base load condition. Even in a state where only the fuel nozzles **21** in the first line are used in this process, the fuel nozzles **21** having the orifices **71** at different axial positions are mixedly present, and planes passing through points of the same phases in the flow rate fluctuation of the fuel that is spouted out from the fuel nozzles **21** are inclined with respect to the burner surface. Thereby, at each step in the process of activation of the gas turbine, it is possible to suppress formation of areas where the phases of the pressure fluctuation and fuel flow rate fluctuation match with each other, and to suppress occurrence of combustion oscillation.

Third Embodiment

—Configuration—

[0060] FIG. **10** is a schematic configuration diagram of the gas turbine power plant including the gas turbine combustor according to a third embodiment of the present invention, and FIG. **11** is a figure of the burner provided to the gas turbine combustor according to the present embodiment as seen from the combustion chamber. The present embodiment is different from the first embodiment and the second embodiment in that the present invention is applied to a multi burner including a plurality of burners. The combustor **3** according to the present embodiment includes a pilot burner **31** and a plurality of main burners **32** (six burners **32** in the present example), and the plurality of main burners **32**

are arranged to surround the circumference of the one pilot burner **31** arranged in the middle. The burner **8** according to the first embodiment or the second embodiment can be applied as the pilot burner **31** and the individual main burners **32**. For example, the burner **8** according to the first embodiment can be applied to all of the pilot burner **31** and the main burners **32**, or the burner **8** according to the second embodiment can be applied to all of the pilot burner **31** and the main burners **32**. The burner **8** according to the first embodiment and the burner **8** according to the second embodiment can also be mixedly present as appropriate. The air hole plate **20** can be shared by the pilot burner **31** and the plurality of main burners **32** (the air holes **51** to **53** for the individual burners can be formed through the one air hole plate **20**).

[0061] In the fuel supplying system **200**, the number of the sets of the branch pipelines **58** and **59** that branch off from the main flow pipeline **57** is equal to the total number (seven in the present example) of the pilot burner **31** and main burners **32**, and the branch pipelines **58** and **59** are connected to the fuel cavities **25** and **26** of corresponding burners. The main burners **32** may be configured such that at least two burners share a fuel supplying system (the branch pipeline **59** and the fuel flow control valve **62**). Similar to the first embodiment and the second embodiment, the main flow pipeline **57** and the branch pipelines **58** and **59** are provided with the fuel shut valve **60**, and the fuel flow control valves **61** and **62**, respectively.

[0062] The present embodiment is similar to the first embodiment and the second embodiment in other aspects.

—Effects—

[0063] By applying the burner configuration according to the first embodiment or the second embodiment to the pilot burner **31** and the main burners **32** to form a multi burner, effects similar to those attained according to the first embodiment, the second embodiment or both the first embodiment and the second embodiment can be attained even if the present invention is applied to a high-capacity gas turbine.

What is claimed is:

1. A gas turbine combustor comprising:

a tubular liner that forms a combustion chamber; and

a burner including

an air hole plate that is arranged at an inlet of the liner and that is provided with a plurality of air holes for guiding compressed air to the combustion chamber, and

a plurality of fuel nozzles arranged on a side opposite to the combustion chamber with the air hole plate being sandwiched therebetween, the plurality of fuel nozzles each injecting a fuel toward a corresponding air hole,

the air holes and the fuel nozzles forming a plurality of concentric annular lines, wherein

the plurality of fuel nozzles each include an orifice on a fuel flow passage, and are grouped into a plurality of nozzle groups, and

axial positions of the orifices are different between the nozzle groups.

2. The gas turbine combustor according to claim **1**, wherein

fuel nozzles grouped into a same nozzle group belong to a same annular line, and the axial positions of the orifices of the fuel nozzles belonging to the same annular line coincide with each other.

3. The gas turbine combustor according to claim **1**, further comprising:

a plurality of fuel cavities that supply a fuel separately to a plurality of fuel nozzles belonging to corresponding annular lines, wherein

the annular lines are grouped into a plurality of areas in a circumferential direction,

fuel nozzles grouped into a same nozzle group belong to a same area, and

fuel nozzles including orifices at different axial positions are mixedly present in a same annular line.

4. The gas turbine combustor according to claim **1**, wherein

opening diameters of orifices belonging to an innermost annular line are larger than opening diameters of orifices belonging to an outermost annular line.

5. The gas turbine combustor according to claim **1**, further comprising:

a plurality of the burners.

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