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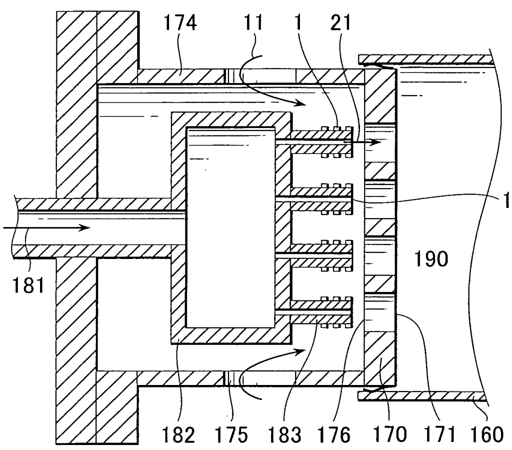
(54) **Burner, method of combustion with the burner, and method of modifying the burner**

(57) The present invention provides a burner that includes fuel nozzles (183) each for jetting out a fuel (21) and air holes (171) each for jetting out air (11), and are constructed so that each of the fuel nozzles (183) is coaxially disposed with the associated one of the air holes (171) to cause each of the fuel nozzles to jet out the fuel into the associated one of the air holes; the burner further having means (1) for disturbing a flow of the fuel (21) or a flow of the air (11) at an upstream position from a nozzle tip (184) disposed to jet out the fuel from the fuel nozzle.

According to the present invention, mixing of the fuel and air existing before both fluids are supplied to a combustion chamber (190) can be promoted for further suppressed NOx emissions.

FIG. 1



EP 1 826 485 A2

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a burner, a method of combustion with the burner, and a method of modifying the burner.

Description of the Related Art

[0002] In recent years, regulations on the emission of air pollutants from burners have been stringent. For gas turbine combustors, for instance, various combustion schemes are under research to reduce the emission levels of the nitrogen oxide (NOx) contained in exhaust gases.

[0003] One of these combustion schemes is coaxial jet combustion in which each of fuel nozzles and each of air holes are arranged to be in essentially coaxial alignment and a fuel and air are supplied to and burned in a combustion chamber as coaxial jets of fluids to form such an air layer that encircles the fuel. This combustion scheme, compared with a conventional premix combustion scheme, makes it possible to promote the mixing of the fuel and the air effectively at a very short distance and thus to reduce NOx emissions.

[Patent Document 1] Japanese Laid-Open Patent Application Publication No. 2004-170010

SUMMARY OF THE INVENTION

[0004] Environmental regulations on the emission levels of NOx from gas turbines and the like, however, are becoming stringent each year from the perspective of the global environment. Further reduction in the emission levels of NOx from current regulation levels will be required in the future.

[0005] Accordingly, an object of the present invention is to further reduce NOx emissions by promoting fuel-air mixing in a coaxial jet combustion scheme.

[0006] The present invention is characterized in that means for disturbing a flow of a fuel or air is disposed at a upstream side with respect to nozzle tips formed to jet out the fuel from fuel nozzles.

[0007] The present invention makes it possible to further reduce NOx emissions by promoting fuel-air mixing in a coaxial jet combustion scheme.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Fig. 1 is a diagram showing, in enlarged form, a peripheral region of fuel nozzles according to a first embodiment of the present invention;
Fig. 2 is a diagram showing, in enlarged form, a peripheral region of fuel nozzles according to a fourth embodiment of the present invention;
Fig. 3 is a diagram showing, in enlarged form, a peripheral region of fuel nozzles according to a fifth embodiment of the present invention;
Fig. 4 is a diagram showing, in enlarged form, a peripheral region of fuel nozzles according to a sixth embodiment of the present invention;
Figs. 5A and 5B are diagrams each showing a flow form at a periphery of the fuel nozzle;
Fig. 6 is a diagram showing, in enlarged form, a peripheral section of a fuel nozzle according to a second embodiment of the present invention;
Fig. 7 is a diagram showing, in enlarged form, a peripheral section of a fuel nozzle according to a third embodiment of the present invention;
Fig. 8 is a diagram showing a flow form at a periphery of the fuel nozzle according to the sixth embodiment;
Figs. 9A and 9B are diagrams each showing, in enlarged form, the periphery of the fuel nozzle having ribs different in height and layout according to the first embodiment;
Fig. 10 is a diagram that shows, in enlarged form, the periphery of the fuel nozzle with ribs being inclined according to the first embodiment;
Figs. 11A and 11B are cross sectional views each showing the fuel nozzle with the ribs each having a gear shape according to the first embodiment;
Figs. 12A and 12B are diagrams each showing, in enlarged form, the fuel nozzle with a flow sleeve according to the first embodiment;
Fig. 13 is a graph that shows combustion test results to compare a fuel nozzle provided with ribs and a fuel nozzle provided without a rib;
Fig. 14 is a diagram schematically showing a mixing boundary layer formed inside an air hole; and
Fig. 15 is a schematic diagram of a structure of a gas turbine.

REFERENCE NUMERALS

[0009] 1, 3 ... Rib, 2, 4 ... Chase, 11 ... Combustion air, 21 ... Fuel, 31 ... Stagnation area, 110 ... Air compressor, 130 ... Diffuser, 140 ... Plenum chamber, 150 ... Transition piece, 151 ... Flow sleeve of the transition piece, 160 ... Liner, 161 ... Outer casing, 170 ... Burner plate, 171 ... Air hole, 172, 173 ... Flow sleeve, 180 ... Fuel pump, 182 ... Fuel header, 183 ... Fuel nozzle, 190 ... Combustion chamber, 191 ... Combustion gas, 200 ... Turbine, 210 ... Electric power generator

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] Embodiments of the present invention will be described below in which a coaxial jet combustion scheme is applied to a gas turbine combustor. The gas turbine combustor is one of burners. In the embodiments, NOx emission levels can be reduced without significantly modifying the coaxial jet combustion scheme.

[0011] Fig. 15 is a schematic diagram showing an entire gas turbine. The gas turbine includes an air compressor 110, a combustor 300, and a turbine 200.

[0012] The air compressor 110 compresses outside air to generate high-pressure air 120. The high-pressure air 120 that has been introduced from the air compressor 110 is further introduced from a diffuser 130 of the combustor into a plenum chamber 140. After this, the high-pressure air 120 flows through a gap between a transition piece 150 and a flow sleeve 151 of the transition piece, the flow sleeve being installed at an outer circumference of the transition piece. Next, the high-pressure air 120 further flows into a gap between a liner 160 and an outer casing 161 disposed at an outer circumference of and concentrically with the liner 160. After that, the direction of the flow of the high-pressure air 120 is inversed. The high-pressure air 120 enters each of air holes 171 provided in a burner plate 170 and is introduced from the air holes 171 into a combustion chamber 190.

[0013] Meanwhile, in a fuel system 181, a fuel that has been boosted in pressure by a fuel pump 180 and adjusted in flow rate by a flow regulating valve 185 is jetted from each of fuel nozzles 183 toward a central portion of the associated one of the air holes 171. The fuel nozzles 183 are provided with a fuel header 182. In this fuel system, the fuel nozzle 183 and the air hole 171 are coaxially disposed so that respective central axes align with each other, the fuel nozzle 183 being provided an upstream side with respect to the air hole 171. The coaxial disposition here means that the fuel nozzle 183 and the air hole 171 are disposed for coaxial alignment between the respective central axes so that the coaxial jet flow that cause air to encircle the fuel will be supplied from the air hole 171. After the fuel has been jetted from the fuel nozzle 183, the fuel and high-pressure air are supplied to the combustion chamber 190 via the air hole 171. The combustion chamber 190 formed inside the liner 160 forms a flame, thus generating a high-temperature high-pressure combustion gas 191.

[0014] The combustion gas 191 that has thus been generated in the combustor is introduced from the transition piece 150 into the turbine 200. The turbine 200 obtains output power from an electric power generator 210 by changing a workload based on the high-temperature high-pressure combustion gas 191 into an axial rotational force. The air compressor 110 and the generator 210 are coupled with the turbine 200 by one shaft. However, the air compressor, the turbine, and the generator may be coupled by two shafts. In addition, although one fuel system 181 is shown in Fig. 15, there is also a fuel system of a multi-combustor structure in which the fuel system is divided into a plurality of subsystems to supply a fuel to a plurality of fuel headers. For example, gas turbines commonly used in thermal power plants or the like have a plurality of combustors arrayed radially with respect to the rotating shaft of the turbine.

[0015] The amount of generated NOx greatly depends on an internal flame temperature of the combustion chamber. As the flame temperature rises, NOx emissions increase exponentially. If the fuel and the air are not sufficiently premixed, therefore, an area of high fuel density is formed locally in the fuel-air gas premixture. Consequently, the flame temperature locally rises, increasing NOx emissions. Accordingly, the fuel and the air must be sufficiently premixed to further reduce NOx.

First Embodiment

[0016] Fig. 1 is an enlarged schematic diagram that shows peripheral sections of fuel nozzles 183 and air holes 171 of a burner in the structure of the gas turbine shown in the schematic diagram of Fig. 15.

[0017] The gas turbine having this structure includes: a fuel header 182 for distributing a fuel from a fuel system 181 to fuel nozzles 183 each located downstream, each fuel nozzle 183 being installed to the fuel header 182; a burner plate 170 having air holes 171 and disposed upstream with respect to a combustion chamber 190, each air hole 171 being provided in the burner plate 170 in order to jet the fuel and air towards the combustion chamber 190; burner sideplates 174 each located upstream with respect to the combustion chamber 190, connected to the burner plate 170, and having the fuel header 182 interposed between the burner sideplates; an air supply hole 175 provided in each burner sideplate 174 in order to supply high-pressure air 120 as combustion air 11 from an air compressor 110 to the air hole 171; liners 160 each for guiding a combustion gas 191 to a transition piece 150 present downstream; and the above-mentioned combustion chamber 190 formed internally to each liner 160 and adapted to burn the fuel and the air. The fuel 21 is jetted from each fuel nozzle 183, towards a central portion of each air hole 171, and the combustion air 11 that has been supplied from an outer surface of the fuel nozzle 183 is jetted together with the fuel 21 into the combustion chamber 190 through the air hole 171. The fuel and air that have been supplied to the combustion chamber 190 form a flame therein. For the combustion chamber 190, a side of the transition piece 150 is defined as a downstream side, whereas a side of the burner plate 170 is defined as an upstream side.

[0018] In the present embodiment, a rib 1 used as means for disturbing a flow of a fuel or air, is provided upstream with respect to a nozzle tip 184 of the fuel nozzle 183. The nozzle tip 184 of the fuel nozzle 183 is a fuel-jetting port positioned downstream with respect to a fuel flow path formed in the fuel nozzle 183. In Fig. 1, the fuel 21 is jetted from the fuel nozzle 183 toward the air hole 171. The high-pressure air 120 that has flown through a gap between the liner 160 and an outer casing 161 flows as the combustion air 11 into a surrounding section of the fuel header 182 through the air supply hole 175 provided upstream with respect to the nozzle tip 184 of the fuel nozzle 183. The air around the fuel header 182 flows into the air hole 171 located downstream, and during the inflow of the air, a great disturbance in the combustion air 11 is given by the rib 1 provided upstream with respect to the nozzle tip 184 of the fuel nozzle 183 in order to disturb the flow of the fuel or air.

[0019] During the occurrence of the above disturbance, the following effect can be considered with respect to a flow form of a mixing boundary layer between the fuel 21 and the combustion air 11:

> Figs. 5A and 5B are diagrams that schematically show different flows of a mixing boundary layer in two different coaxial jet combustion schemes. Fig. 5A shows a comparative example for a better understanding of the present embodiment. In the comparative example, rib 1 used as means for disturbing a flow of fuel or air is not provided upstream with respect to a nozzle tip of a fuel nozzle. In this comparative example, since combustion air 11 flows downstream along an outer surface of the fuel nozzle 183 of a cylindrical shape without being disturbed, a stagnation area 31 formed at a downstream position of a member forming the fuel nozzle 183 is small and thus a disturbance in a mixing boundary layer between the fuel 21 and the air 11 is insignificant. Required thickness exists in the member that forms the fuel nozzle 183, and this thick section causes the stagnation area 31 to be formed in a neighboring portion of an immediate downstream end of the thick section. Also, the mixing boundary layer is formed at a downstream side of the stagnation area 31. In this way, in the comparative example, such an air layer is formed that is essentially coaxial with an axial center of a fuel jet and encircles the fuel. Additionally, the mixing boundary layer between the fuel 21 and the air 11 is not significantly disturbed. For these reasons, the fuel 21 and the combustion air 11 are not uniformly mixed before being supplied to a combustion chamber 190 by flowing from the nozzle tip 184 of the fuel nozzle 183 into the combustion chamber.

[0020] In contrast to the above, in the structure of the present embodiment that is shown in Fig. 5B, the means, which is provided at the upstream side from the nozzle tip 184 of the fuel nozzle 183 in order to disturb a flow of fuel or air, causes a disturbance to the combustion air 11 at the upstream side from the nozzle tip 184 of the fuel nozzle 183. The combustion air 11 that has been supplied from the air supply hole 175 provided at the upstream side from the nozzle tip 184 of the fuel nozzle 183 is considered to be supplied to the air hole 171 after being disturbed by the means for disturbing a fuel flow or airflow when flowing along the outer surface of the fuel nozzle 183 first and then into the air hole 171. A stagnation area 31 formed upstream with respect to the fuel nozzle 183 is therefore spread more than in the comparative example. The fuel 21 and the combustion air 11 consequently flow into a downstream space with respect to the stagnation area 31, thus forming flows of both the fluids that collide and are mixed with each other. It is considered, therefore, that the mixing boundary layer formed at the downstream side of the stagnation area 31 is also spread more than in the comparative example.

[0021] Fig. 14 is a diagram showing the mixing boundary layer considered to be formed in the air hole 171. In addition, Fig. 14 schematically shows each fluid layer considered to be formed in section A-A of the air hole 171 shown in Fig. 5B. Inside the air hole 171, a layer of fuel 21 is considered to be formed centrally in the air hole, and a layer of combustion air 11 is considered to be formed at the position closest to an inner wall of the air hole. A layer present between the fuel 21 and the combustion air 11 is the mixing boundary layer 41. Although each layer is obviously separated with each other as shown in Fig. 14, actual fuel densities are considered to be continuously distributed. In the present embodiment, increasing the mixing boundary layer 41 in cross-sectional area can reduce the layer of fuel 21 and the layer of combustion air 11 in a relative fashion and increase amounts of the combustion air and the fuel in a mixture.

[0022] Before the fuel 21 and the combustion air 11 flow from the nozzle tip 184 of the fuel nozzle 183 into the combustion chamber 190, therefore, the mixing of the fuel 21 and the combustion air 11 can be uniformized more than in the comparative example. Uniformizing the mixture of the fuel 21 and the combustion air 11 in this fashion before the mixture flows into the combustion chamber makes it possible to suppress local rises in flame temperature and thus to reduce NOx emissions.

[0023] Fig. 13 is a diagram that shows combustion test results on NOx emission characteristics. These test results are plotted with a combustion gas temperature taken on a horizontal axis and an NOx emission level on a vertical axis, in the case of the fuel nozzle provided with ribs at the nozzle tip in order to disturb the flow of the fuel or air and in the case of a fuel nozzle provided without a rib. Fig. 13 clearly indicates that NOx emissions can be reliably reduced by providing the ribs on the fuel nozzle. Providing the ribs increases the stagnation area in size at the downstream section of the fuel nozzle, thus spreading the mixing boundary area formed between the fuel and the combustion air. Hence, it is considered that the mixture of the fuel and combustion air existing before a mixture of both the fuel and combustion air flows into the combustion chamber can be made more uniform than in the comparative example, and thus NOx emissions are reduced.

[0024] To increase the size of the stagnation area 31 formed at the downstream side of the fuel nozzle 183, it is considered that a method is used to increase the thickness of the member forming the cylindrical fuel nozzle 183. A majority of gas turbine combustors, however, use an air temperature of about 400°C and a fuel temperature of 100°C or less. Therefore, thickening the fuel nozzle 183 uniformly in a direction of jetting out the fuel may cause the member of the fuel nozzle 183 to be damaged by an increase in heat stress due to a temperature difference between the interior and exterior of the fuel nozzle. Thickening the fuel nozzle 183 is also considered to narrow an airflow path between fuel nozzles, thus making the combustion air 11 difficult to flow. For these reasons, it is desirable that as in the present embodiment, part of the fuel nozzle 183 should have the rib 1 that disturbs the flow of the fuel or air.

[0025] Properly improving a shape of the rib 1 also makes it possible to easily disturb the above flow. In addition, the flow can be easily disturbed without adding other accessory parts.

[0026] In the present embodiment, the means for disturbing the flow of the fuel or air has members of ring shape. The members of ring shape are vertical to the central axis of the fuel nozzle 183 and provided on the outer circumference side of the fuel nozzle. In the present embodiment, a nozzle tip side is defined as a side at which the nozzle tip is positioned to jet out the fuel from the fuel nozzle 183, and a supply side is defined as a side at which the fuel header 182 is provided. The rib 1, for example, is a protruding member with a required thickness and is provided abutting the outer circumference side of the cylindrical fuel nozzle 183. The rib 1 has a predetermined height. The ring-shaped members shown in Fig. 1 are positioned at the nozzle tip side and on the outer circumference side of the fuel nozzle 183. Also, the ring-shaped members are vertical to the central axis of the fuel nozzle 183. The rib 1 disposed on the fuel nozzle 183 desirably has a height in the radial direction so that the combustion air 11 is disturbed to form the stagnation area 31 at the downstream side, the stagnation area 31 being larger than in the comparative example. Since the rib 1 is thus provided on the outer circumference section of the fuel nozzle 183 and on the nozzle tip side, a distance between the fuel and combustion air at the nozzle tip 184 of the fuel nozzle 183 is increased and the stagnation area 31 is correspondingly increased in size, compared with in the comparative example. Therefore, the mixing boundary layer between the fuel 21 and the combustion air 11 is further spread for an increased mixing rate of the fuel and combustion air jetted into the combustion chamber 190. As a result, as the mixing boundary layer is made larger, the mixing of the fuel and the combustion air is promoted, which makes it possible to suppress local rises in flame temperature and reduce NOx emissions.

[0027] It is also possible to provide a plurality of ribs 1, not one only, at the supply side in the fuel-jetting direction of the fuel nozzle 183. That is to say, a plurality of ribs may be installed on the entire surface from the nozzle tip side of the fuel nozzle 183 to the supply side, instead of a rib being installed only at the nozzle tip side of the fuel nozzle 183.

[0028] Alternatively, the fuel nozzle 183 may, as shown in Fig. 9A, be constructed so that ribs are progressively smaller in height in a direction from the nozzle tip side of the fuel nozzle 183 toward the supply side. This is because, if all ribs 1 are formed with the same height, the ribs at the supply side that do not directly contribute to the formation of the stagnation area may increase airflow pressure loss. Adopting the structure shown in Fig. 9A, therefore, is likewise useful for suppressing increases in airflow pressure loss and for applying an effective disturbance to the mixing boundary layer of the fuel and air. Similar positive effects are expected to be obtainable by, as shown in Fig. 9B, increasing arrangement pitches of ribs in order from the nozzle tip side toward the supply side.

[0029] Further, as shown in Fig. 10, an alternative structure may be used so that the rib 1 is not only orthogonal to the central axis of the fuel nozzle 183, but also inclined with respect to the central axis of the fuel nozzle. Providing a rib of this inclined structure applies a whirling component to the flow of air before the fuel and the air are supplied to the combustion chamber. Consequently, the mixing of the fuel and the air is further promoted.

[0030] A further alternative method is by, as shown in Fig. 11A or 11B, slitting the rib with respect to a circumferential direction of the fuel nozzle 183 so that the rib has a shape of a gear, not merely such a ring shape as shown in Fig. 10. The slitting forms a vertical vortex and horizontal vortex of the combustion air, thus generating a significant disturbance. This, in turn, further promotes the mixing of the fuel and the combustion air before these fluids are supplied to the combustion chamber, and makes NOx emissions reducible.

[0031] Moreover, for an existing burner of the coaxial jet combustion scheme, the fuel nozzle is desirably modified since an NOx reduction effect is expected to be obtainable just by changing the shape of the fuel nozzle. More specifically, a fuel header with a plurality of fuel nozzles each having means for disturbing a fuel-flow or airflow at an upstream side with respect to a nozzle tip which jets out a fuel from the fuel nozzle is manufactured in a separate process beforehand. This makes the existing burner easily modifiable on a fuel header basis just by replacing the original fuel nozzle of the burner, without modifying other sections.

Second Embodiment

[0032] Fig. 6 is a diagram showing in enlarged form a peripheral section of a fuel nozzle according to a second embodiment.

[0033] This structure is essentially the same as that of the first embodiment, except that a fuel nozzle 183 has chases 2 on an outer surface of the fuel nozzle and at a nozzle tip side. A fuel 21 is jetted from the fuel nozzle 183 toward a central portion of an air hole 171, and combustion air 11 flows around the fuel 21 and is jetted from the air hole 171 into a combustion chamber 190. The fuel and the combustion air form a flame in the combustion chamber 190.

[0034] In the present embodiment, the fuel nozzle 183 includes the chases 2 at its peripheral side. The chases

2 are formed so as to reduce a member of the fuel nozzle 183 in circumferential thickness at fixed depth. Providing the chases 2 in this way on the outer surface of the fuel nozzle 183 also applies a significant disturbance to a mixing boundary layer formed between the fuel 21 and the combustion air 11, at a downstream section of the fuel nozzle 183. The disturbance makes it possible to promote mixing of the two fluids before both are supplied to the combustion chamber. As a result, local rises in flame temperature can be suppressed for reduced NOx emissions.

[0035] Fig. 6 also shows a flow form of the mixing boundary layer considered to be formed by the fuel 21 and the combustion air 11, according to the present embodiment. Basic effects are the same as in the first embodiment. That is to say, each chase 2 on the outer surface of the fuel nozzle 183, near the nozzle tip of the fuel nozzle, gives a disturbance to a flow of the air 11, whereby a stagnation area 31 formed at the downstream side of the fuel nozzle 183 is spread more than in the comparative example. When the combustion air 11 collides with the chase 2, a stream that pulls the combustion air away from the fuel 21 outward in a radial direction is generated in the air and the stagnation area 31 is further spread. A colliding and mixing flow of the fuel 21 and combustion air 11 is consequently formed at a downstream side of the stagnation area 31, thus creating a more uniform fuel-air mixture than in the comparative example. The mixing of the fuel and the air is therefore promoted before both are supplied to the combustion chamber, such that NOx can be further reduced.

[0036] The chase 2 shown in the second embodiment may be provided not only at a nozzle tip side of the fuel nozzle 183, but also in a plurality of places at a supply side of the fuel nozzle 183.

[0037] In addition, all chases 2 in that case may be formed with the same depth. Alternatively, however, the fuel nozzle 183 may be constructed so that the chases are progressively shallower in a direction from the nozzle tip side of the fuel nozzle 183 toward the supply side (i.e., an upstream side with respect to the jetting direction of the fuel nozzle 183). This construction suppresses an increase in airflow pressure loss and applies an effective disturbance to the mixing boundary layer of the fuel and the air. Similar positive effects are expected to be obtainable by increasing layout pitches of each chase 2 in order from the nozzle tip side toward the supply side.

[0038] Further, an alternative structure may be used so that the chase 2 is not only orthogonal to a central axis of the fuel nozzle 183 but also inclined with respect to the central axis of the fuel nozzle. Inclining the chase 2 in this way with respect to the central axis of the fuel nozzle 183 applies a whirling component to the flow of the air and further promotes the mixing of the fuel and the air before both fluids are supplied to the combustion chamber.

Third Embodiment

[0039] Fig. 7 is a diagram showing in enlarged form a peripheral section of a fuel nozzle in a third embodiment.

[0040] This structure is essentially the same as that of the first embodiment, except that a fuel nozzle 183 has a rib 3 on an inner surface of the fuel nozzle, near a nozzle tip thereof. A fuel 21 is jetted from the fuel nozzle 183 toward a central portion of an air hole 171, and air 11 is jetted from the air hole 171 into a combustion chamber 190. The fuel forms a flame in the combustion chamber 190.

[0041] In the present embodiment, the rib 3, which is an annular member disposed on the inner surface of the fuel nozzle 183 and near the nozzle tip thereof, applies a significant disturbance to a mixing boundary layer formed between the fuel 21 and the air 11, at a downstream section of the fuel nozzle 183, thereby to promote mixing of the two fluids. As a result, local rises in flame temperature can be suppressed for reduced NOx emissions.

[0042] Fig. 7 is an explanatory diagram of a flow form of the mixing boundary layer considered to be formed by the fuel 21 and the combustion air 11. The rib 3 is a ring-shaped member of a required height, abutting the inner surface of the fuel nozzle 183. The rib 3 can apply a disturbance to a flow of the fuel 21 inside the fuel nozzle 183 since the rib is provided so as to disturb the flow. The fuel 21 is not only applied a disturbance in this way, but also pulled away from the combustion air 11 at the nozzle tip of the fuel nozzle 183, whereby a stagnation area 31 formed downstream with respect to the fuel nozzle 183 is spread more than in the comparative example. Consequently, the fuel 21 and the combustion air 11 flow into a downstream section of the stagnation area 31, then a colliding and mixing flow of both fluids is formed, and a mixture thereof existing before being supplied to the combustion chamber is uniformized more than in the comparative example. Accordingly, local rises in flame temperature can be suppressed and NOx emissions reduced.

[0043] The rib 3 shown in the third embodiment can also be provided upstream at a plurality of positions within the fuel nozzle 183, along a fuel injection path thereof.

[0044] In that case, all ribs 3 may be formed with the same height. Instead, however, the fuel nozzle 183 may be constructed so that ribs 3 are progressively smaller in height in a direction from the nozzle tip side of the fuel nozzle 183 toward the supply side. This construction suppresses an increase in airflow pressure loss and applies an effective disturbance to the mixing boundary layer of the fuel and the air. Similar positive effects are expected to be obtainable by increasing layout pitches of each rib 3 in order from the nozzle tip side toward the supply side.

[0045] Further, an alternative structure may be used so that the rib 3 is not only orthogonal to a central axis of the fuel nozzle 183 but also inclined with respect to the central axis of the fuel nozzle. Inclining the rib 3 in this way with respect to the central axis of the fuel nozzle 183 applies a whirling component to the flow of the fuel and promotes the mixing of the fuel and the air before both fluids are supplied to the combustion chamber.

[0046] Furthermore, slitting the rib 3 in a circumferential direction thereof forms a vertical vortex and horizontal vortex of the fuel at a downstream side of the rib, thus causing a significant disturbance, further promoting the mixing of the fuel and the air, and making NOx emissions reducible.

Fourth Embodiment

[0047] Fig. 2 is a diagram showing in enlarged form a peripheral region of fuel nozzles in a fourth embodiment.

[0048] This structure is essentially the same as that of the first embodiment, except that the fuel nozzles 183 each have a chase 4 on an inner surface of the fuel nozzle, near a nozzle tip thereof. A fuel 21 is jetted from the fuel nozzle 183 toward a central portion of an associated air hole 171, and combustion air 11 is jetted from the air hole 171 into a combustion chamber 190. The fuel 21 forms a flame in the combustion chamber 190.

[0049] In the present embodiment, providing the chase 4 on the inner surface of each fuel nozzle 183 applies a significant disturbance to a mixing boundary layer formed between the fuel 21 and the combustion air 11, at a downstream section of the fuel nozzle 183, and promotes mixing of the two fluids existing before both fluids are supplied to the combustion chamber. As a result, local rises in flame temperature can be suppressed for reduced NOx emissions.

[0050] The chases shown in the fourth embodiment may be provided not only at the nozzle tip of each fuel nozzle 183, but also in multi-stage form at upstream positions thereof in an injection direction of the fuel.

[0051] In addition, all chases in that case may be formed with the same depth. Instead, however, the fuel nozzle 183 may be constructed so that each chase is progressively shallower in a direction from the nozzle tip side of the fuel nozzle 183 toward the supply side. Similar positive effects are expected to be obtainable by increasing layout pitches of each chase in order from the nozzle tip side, towards the supply side.

[0052] Further, an alternative structure may be used so that the chase 4 is not only orthogonal to a central axis of the fuel nozzle but also inclined with respect to the central axis of the nozzle. Inclining the chase 4 in this way applies a whirling component to the flow of the fuel, thus making it possible to further promote the mixing of the fuel and the air.

Fifth Embodiment

[0053] Fig. 3 is a diagram showing in enlarged form a peripheral region of fuel nozzles in a fifth embodiment.

[0054] This structure is essentially the same as that of the first embodiment, except that the fuel nozzles 183 each have an inclination 5 at a nozzle tip of the fuel nozzle 183. A fuel 21 is jetted from the fuel nozzle 183 toward a central portion of an associated air hole 171, and combustion air 11 is jetted from the air hole 171 into a combustion chamber 190. The fuel 21 forms a flame in the combustion chamber 190.

[0055] In the present embodiment, the fuel nozzle 183 has a wide portion of an inclined shape that is disposed at its nozzle tip and progressively increases a member of the fuel nozzle in thickness. The wide portion temporarily pulls the combustion air 11 away from the fuel 21, then spreads a stagnation area, and applies a significant disturbance to a mixing boundary layer later, which is formed between the fuel 21 and the combustion air 11 and at a downstream section of the fuel nozzle 183. Thus, mixing of the two fluids can be promoted before both fluids are supplied to the combustion chamber. As a result, local rises in flame temperature can be suppressed for reduced NOx emissions.

[0056] In addition, slitting the inclined portion shown in the fifth embodiment in a direction of the circumference of the inclined portion forms a vertical vortex and horizontal vortex of the combustion air at a downstream position of the inclined portion, thus generates a significant disturbance and promotes the mixing of the fuel and the air. Thus, NOx emissions can be reduced.

Sixth Embodiment

[0057] Fig. 4 is a diagram showing in enlarged form a peripheral region of fuel nozzles in a sixth embodiment.

[0058] In the present embodiment, each fuel nozzle has a nozzle tip inserted in an associated air hole in the structure of the burner described in any one of the above first to fifth embodiments. Other structural aspects are essentially the same as those of the first embodiment.

[0059] Fig. 8 shows a flow form of a mixing boundary layer considered to be formed by a fuel 21 and combustion air 11. As shown in Fig. 8, disposing the fuel-jetting nozzle tip 184 of the fuel nozzle 183 inside the air hole 171 is considered to increase air velocity near ribs 1 provided on the fuel nozzle 183, and thus to significantly disturb the air in the mixing boundary layer. A stagnation area 31 formed downstream with respect to the fuel nozzle 183 is therefore increased in size, and at the same time, the fuel and combustion air flowing into a downstream section of the fuel nozzle 183 are also enhanced in velocity. This further promotes mixing of the fuel and the air, resulting in reduced NOx emissions.

[0060] If, as shown in Fig. 12A, a flow sleeve 172, which is a member with the same inside diameter as that of the air hole 171 are installed at an inlet of the air hole 171 to shroud a neighboring section of the nozzle tip 184 of the fuel nozzle 183, this structure makes it possible to obtain positive effects similar to those obtained by inserting the fuel nozzle into the air hole. Furthermore, as shown in Fig. 12B, forming a flow sleeve 173 may be conically formed so that the inside diameter increase in an upstream direction of the fuel nozzle.

[0061] In addition to gas turbine combustors, the burners shown in the foregoing first to sixth embodiments can be applied as various burners/combustors fueled by a methane gas or the like, such as a combustor for fuel reforming in a fuel cell, a combustor for a boiler, a warm-air heater, and an incinerator.

[0062] The present burner structures can be applied not only to gas turbines but also to combustors for boilers, combustors for fuel reforming in fuel cells, and other various devices that burn gaseous fuels.

Claims

1. A burner comprising:

fuel nozzles (183) each of which jets out a fuel (21); and
air holes (171) each of which jets out air (11);
each of the fuel nozzles (183) and each of the air holes (171) being arranged to be essentially coaxial with each other to cause each of the fuel nozzles to jet out the fuel (21) into the associated one of the air holes (171);

wherein the burner further comprises means for disturbing a flow of the fuel (21) or a flow of the air (11) at an upstream side with respect to a nozzle tip (184) disposed to jet out the fuel from the fuel nozzle.

2. A burner comprising:

fuel nozzles (183) each of which jets a fuel (21); and
air holes (171) each of which jets air (11);
each of the fuel nozzles (183) and each of the air holes (171) being arranged to be essentially coaxial with each other to cause each of the fuel nozzles to jet out the fuel (21) into the associated one of the air holes (171);

wherein each of the fuel nozzles (183) includes:

a nozzle tip (184) disposed to jet out the fuel (21) into the associated one of the air holes (171); and
means (1 to 5) for disturbing a flow of the fuel (21) or a flow of the air (11) at an upstream side with respect to the nozzle tip (184) of the fuel nozzle.

3. A burner comprising:

a combustion chamber (190) which burns a fuel and air;
fuel nozzles (183) each of which supplies the fuel (21) to the combustion chamber (190); and
air holes (171) each of which is disposed coaxially with a central axis of the associated one of the fuel nozzles (183) and supplies the air to the combustion chamber (190);

wherein a nozzle tip (184) of each of the fuel nozzle (183) is disposed to jet out the fuel (21) into the associated one of the air holes (171); and
wherein at an upstream side with respect to each of the nozzle tips (184), an annular member is provided on an outer surface of the fuel nozzle of a cylindrical shape and near the nozzle tip.

4. The burner according to claim 1, wherein the means for disturbing a flow of the fuel (21) or a flow of the air (11) is a chase (2) provided on an outer surface of the fuel nozzle (183).

5. The burner according to claim 1, wherein the means for disturbing a flow of the fuel (21) or of the air (11) is an annular member (3) provided on an inner surface of the fuel nozzle (183).

6. The burner according to claim 1, wherein the means for disturbing a flow of the fuel (21) or a flow of the air (11) is a member (5) including an inclination provided on an outer surface of the fuel nozzle (183) and near the nozzle tip.

7. The burner according to claim 1, wherein a flow sleeve (172) that shrouds the nozzle tip (184) of the fuel nozzle (183) is provided in the air hole (171).

8. A method of combustion with a burner, the method comprising the steps of:

jetting out a fuel (21) from each of fuel nozzles (183); and
jetting out air (11) from air holes (171) each disposed downstream with respect to the associated one of the fuel nozzles, each air hole being coaxial with a central axis of the associated fuel nozzle;

wherein the fuel (21) or the air (11) that has a flow (31) disturbed upstream with respect to a position of jetting out the fuel from each of the fuel nozzles (183) is supplied to the associated one of the air holes (171).

9. A method of combustion with a burner, the method comprising the steps of:

jetting out a fuel (21) from each of fuel nozzles (183); and
jetting out air (11) from air holes (171) each disposed coaxially with a central axis of the associated one of the fuel nozzles;

wherein the fuel (21) is jetted into each air hole (171); and
wherein the fuel (21) or the air (11) that has a flow (31) disturbed upstream with respect to a position of jetting out the fuel from each of the fuel nozzles (183) is supplied to the associated one of the air holes (171).

10. A method of modifying a burner which comprises:

a fuel header (182) provided with a plurality of fuel nozzles (183) each for jetting out a fuel (21); and
air holes (171) each for jetting out air (11);
the fuel header (182) being disposed so that each of the fuel nozzles is coaxially disposed with the associated one of the air holes whereby each of the fuel nozzles jets out the fuel into the associated one of the air holes;

wherein the fuel header (182) is replaced with another fuel header (182) having a plurality of fuel nozzles (183) that each include means (1 to 5) for disturbing a flow (31) of the fuel or a flow of the air at an upstream side with respect to each of nozzle tips (184) disposed to jet out the fuel (21) from the fuel nozzles (183).

FIG. 1

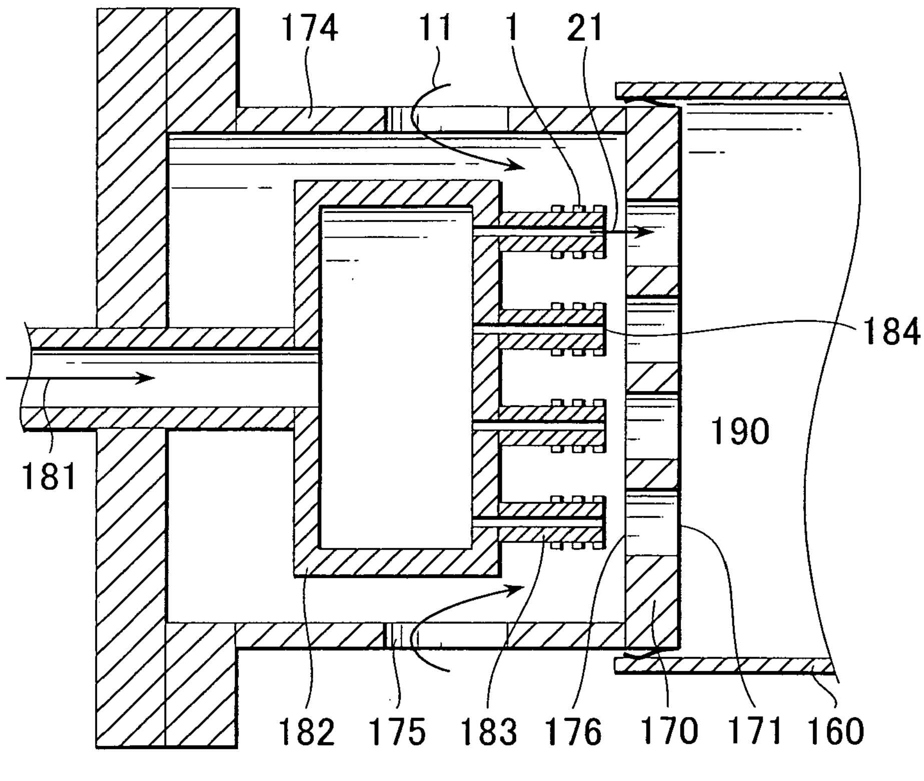


FIG. 2

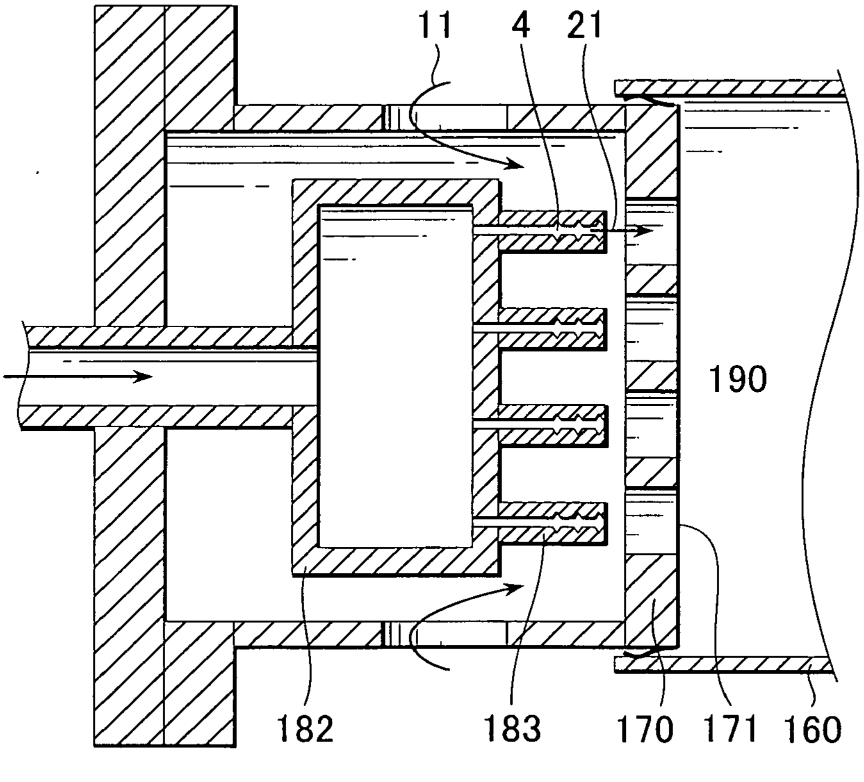


FIG. 3

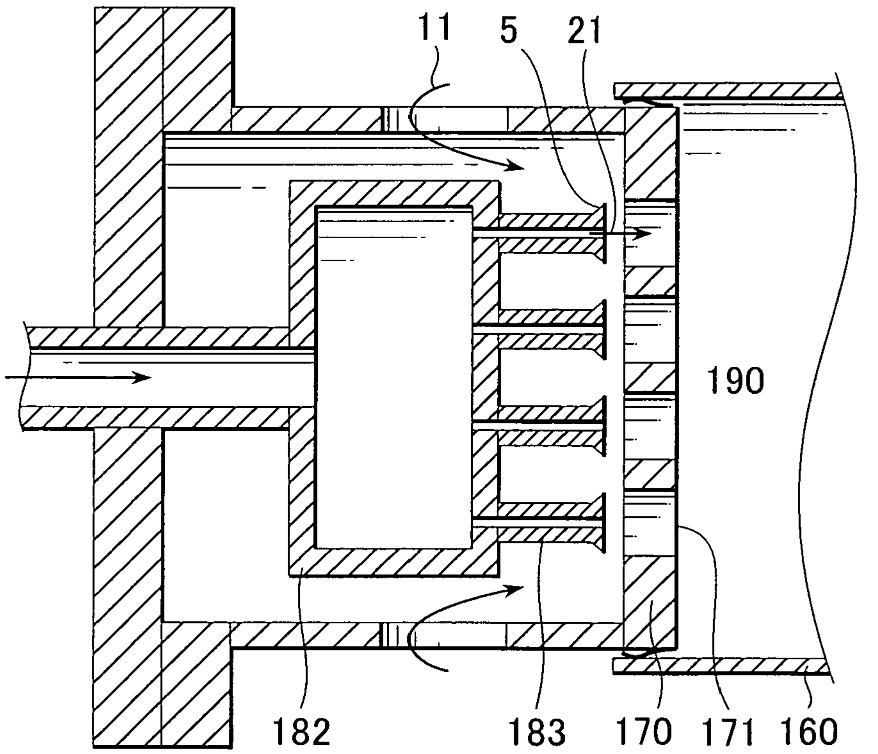


FIG. 4

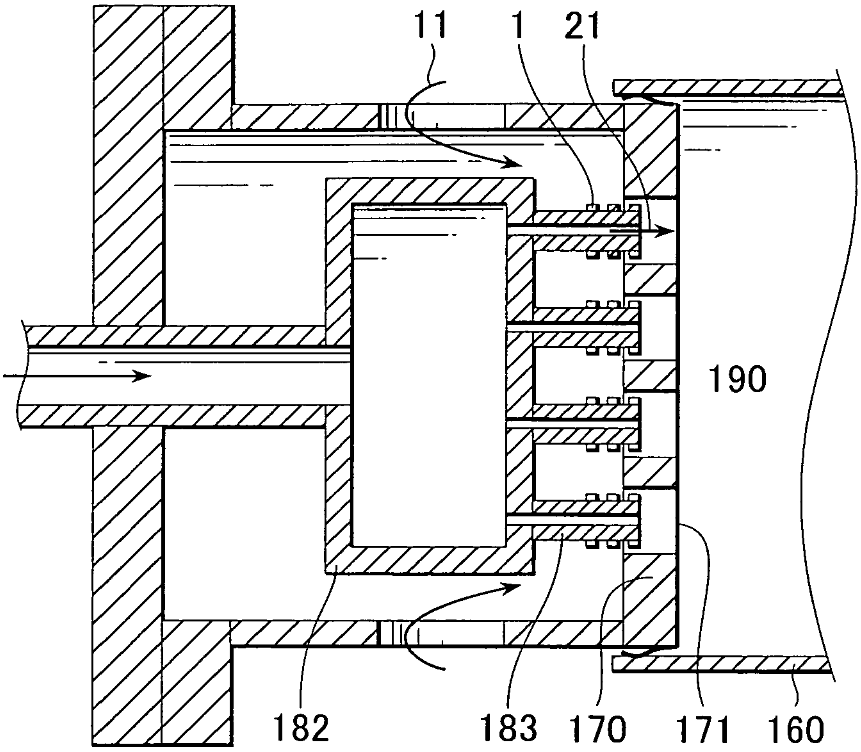


FIG. 5A

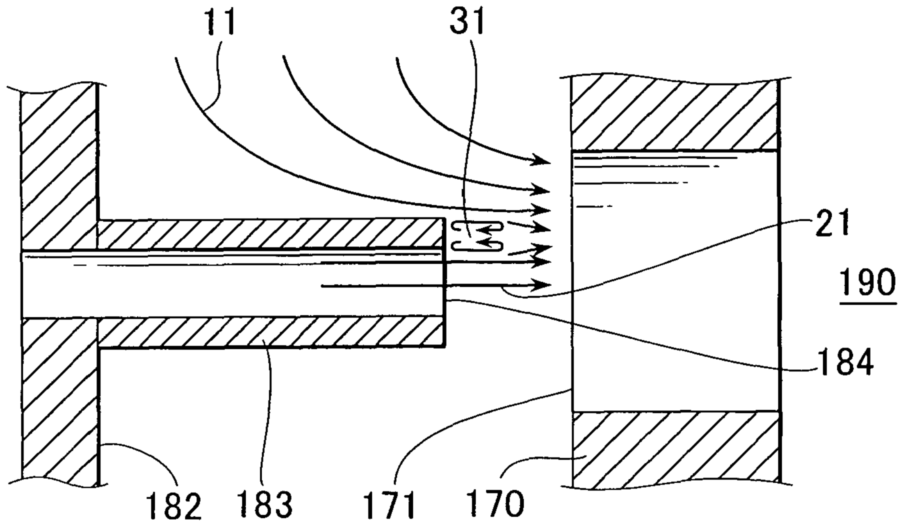


FIG. 5B

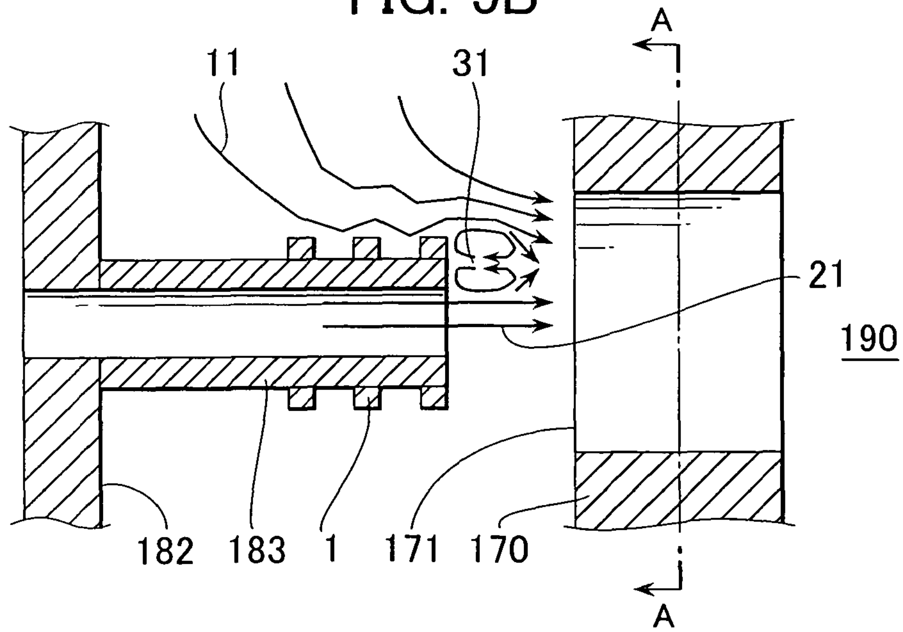


FIG. 6

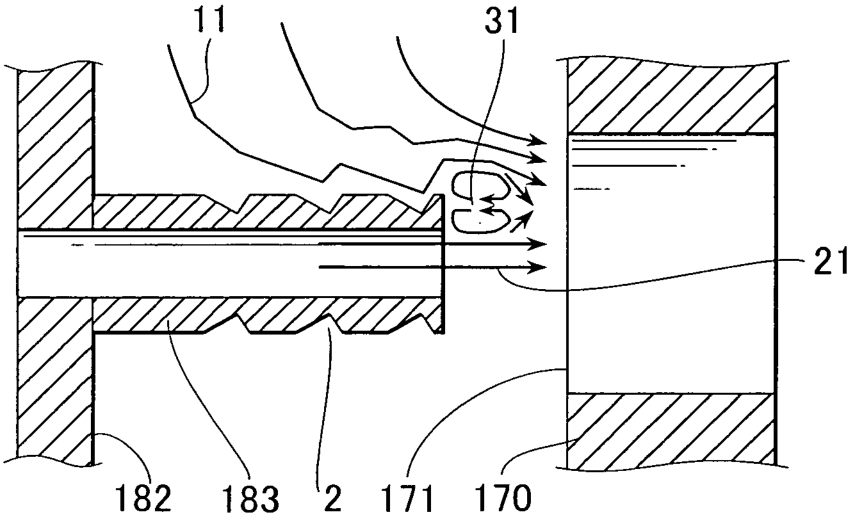


FIG. 7

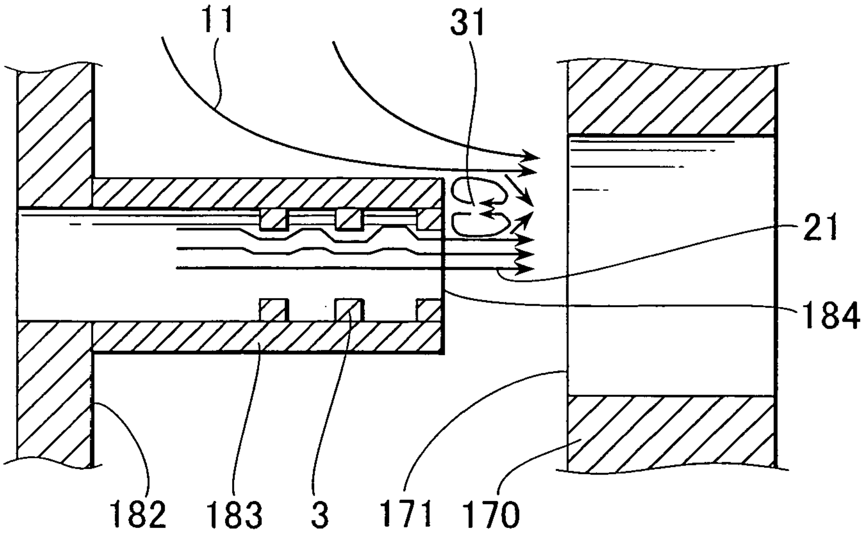


FIG. 8

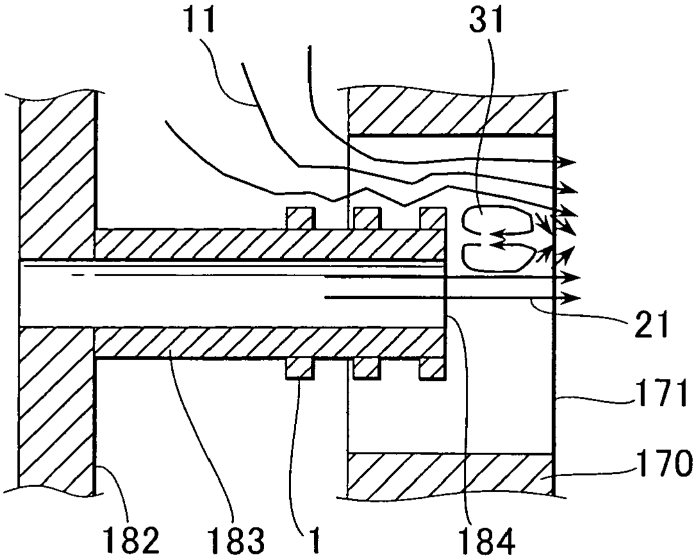


FIG. 9A

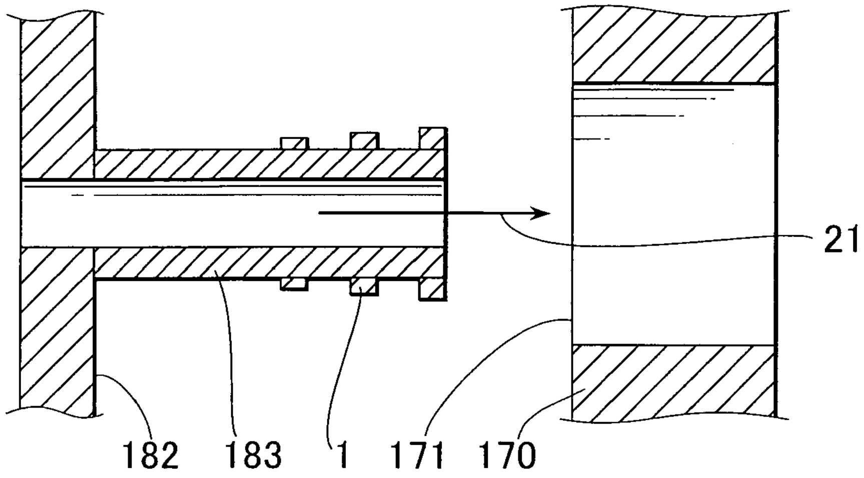


FIG. 9B

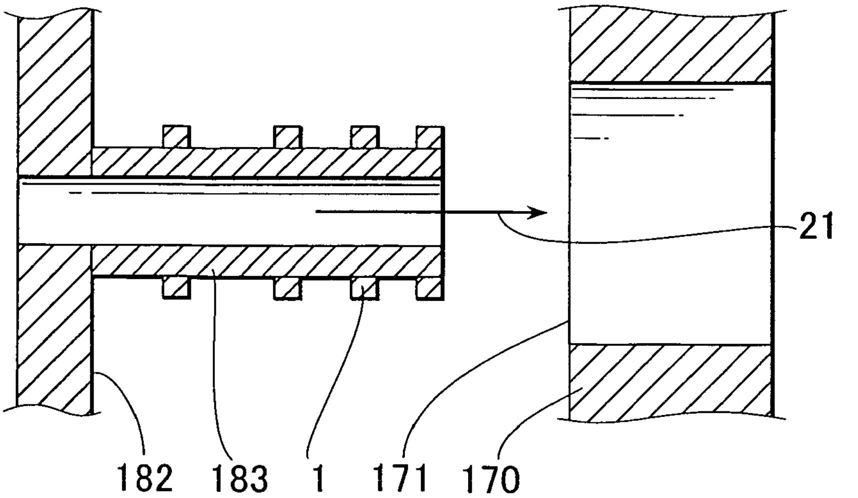


FIG. 10

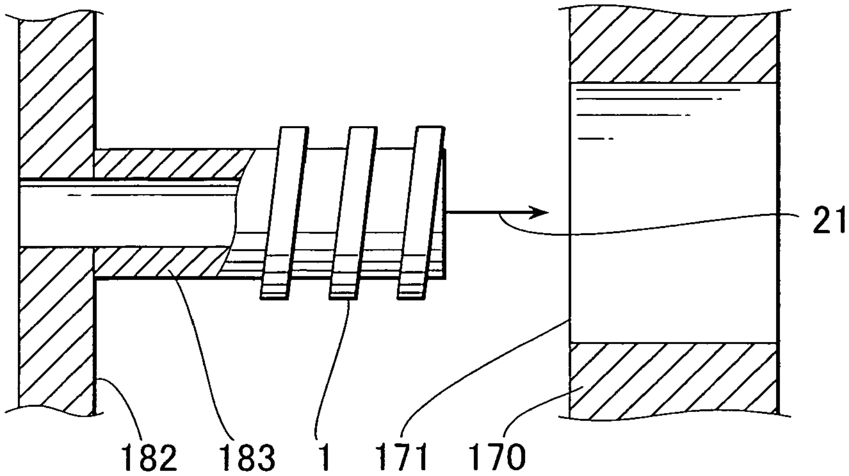


FIG. 11A

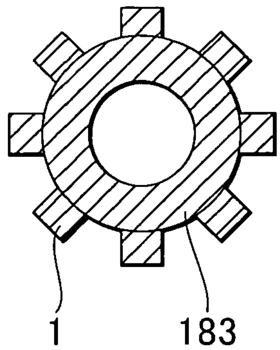


FIG. 11B

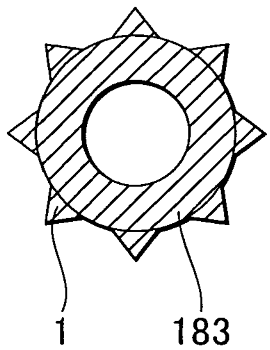


FIG. 12A

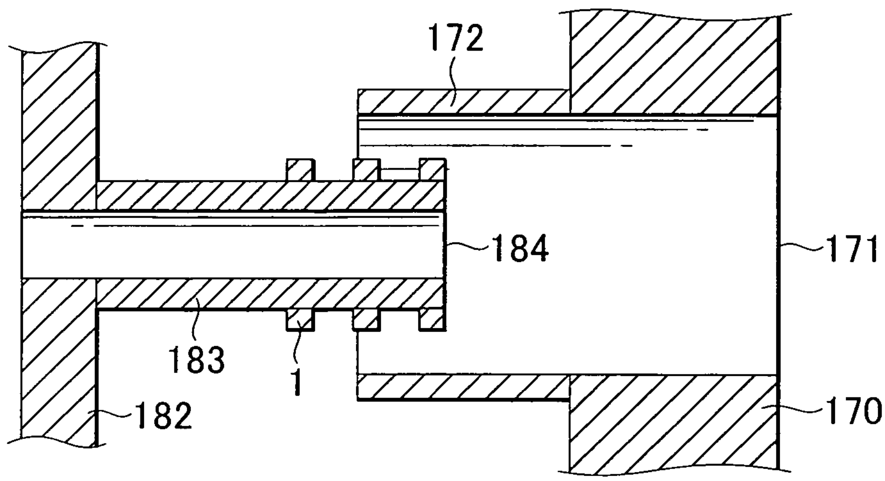


FIG. 12B

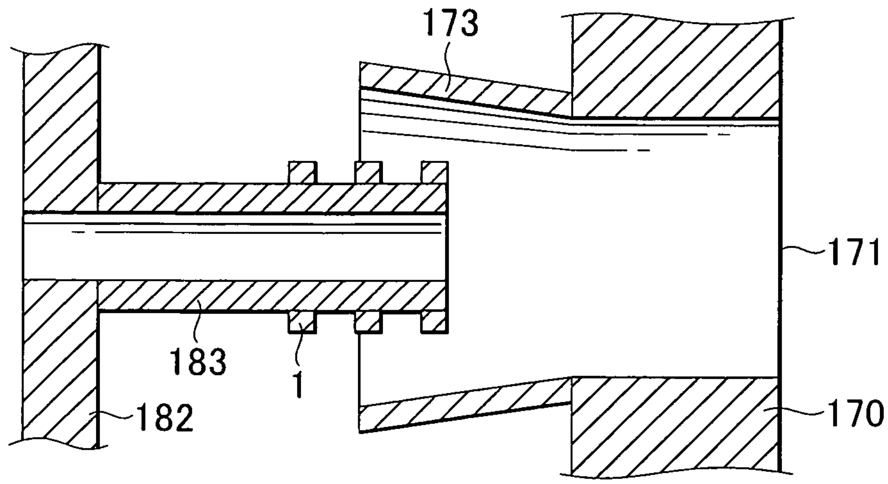


FIG. 13

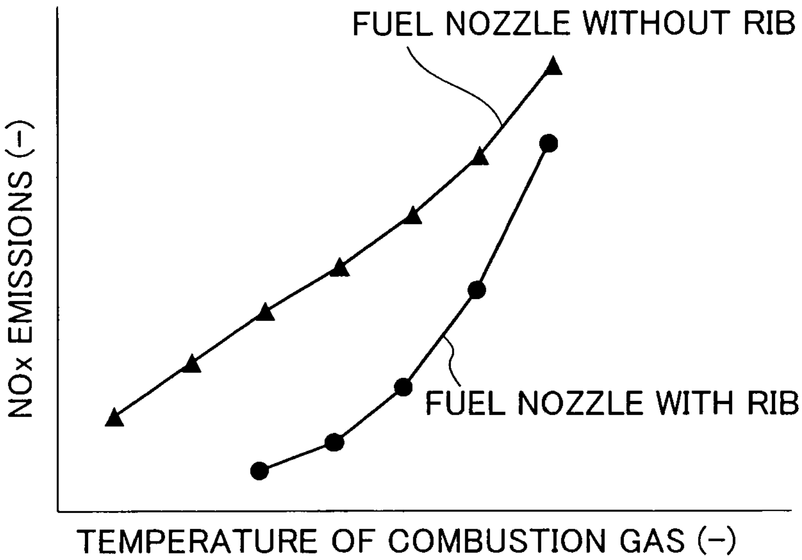

FUEL NOZZLE WITHOUT RIB
FUEL NOZZLE WITH RIB
NOx EMISSIONS (-)
TEMPERATURE OF COMBUSTION GAS (-)

FIG. 14

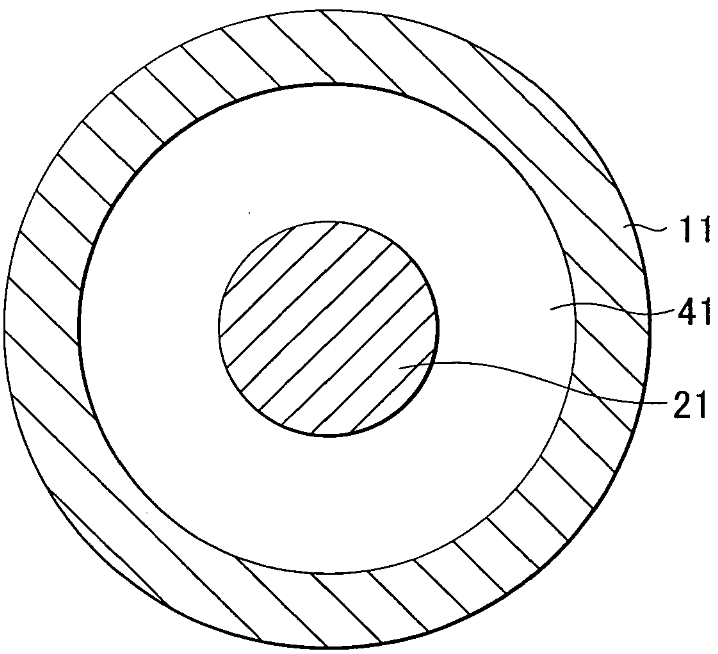
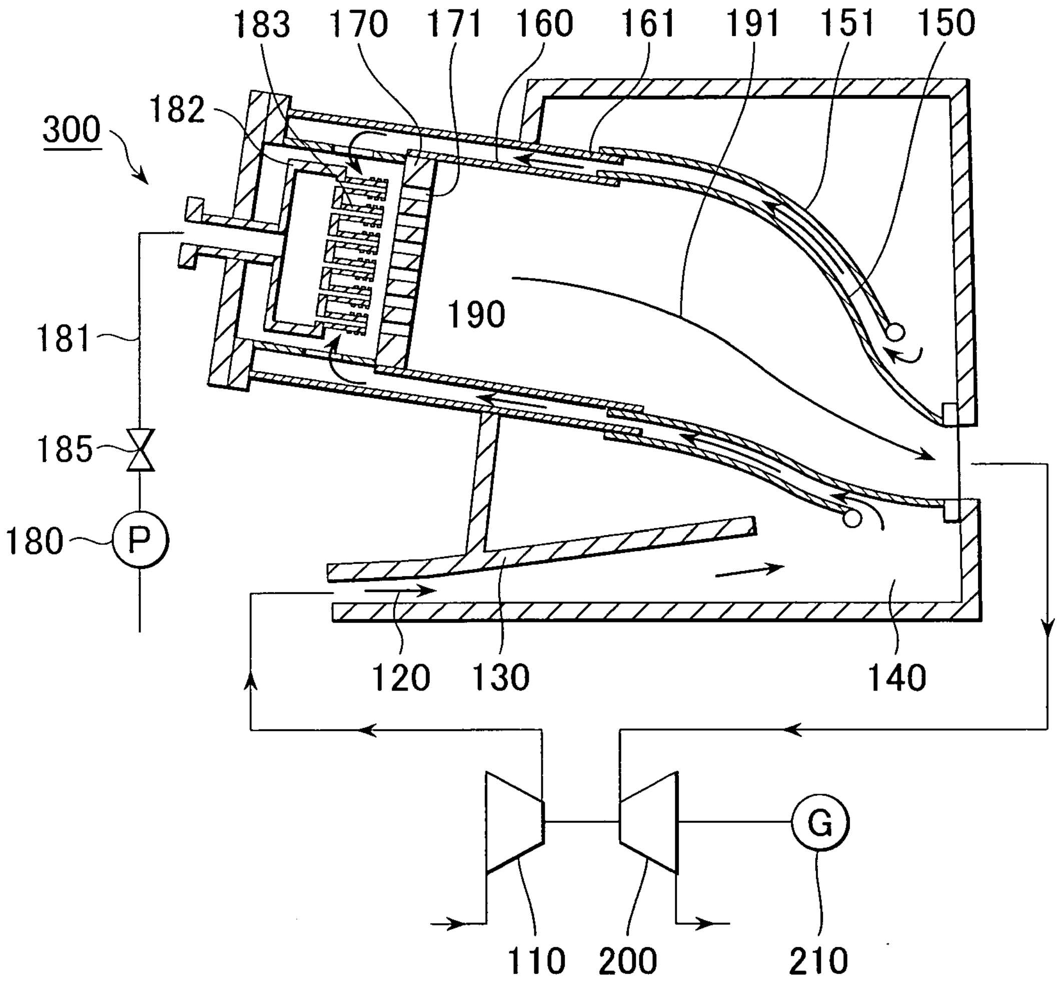

11
41
21

FIG. 15


183
170
171
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161
191
151
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182
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185
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P
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200
210
G

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Patent documents cited in the description

- JP 2004170010 A **[0003]**