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(54) **Fuel nozzle for premix turbine combustor**

(57) This invention relates to a fuel discharge member which can reduce the amount of NO_x exhaust. The fuel discharge member is fixed on a fuel supply conduit (17), and comprises: a main body (23) having an internal space (22) which communicates with a fuel passage in the fuel supply conduit, fuel discharge outlets (21) which

communicate with the internal space, and a trailing edge (23a). The thickness (t) of the trailing edge is no more than 5mm, or a flow passage block ratio of the fuel discharge member is no more than 10% with respect to the cross-sectional area of the air flow passage in which the fuel discharge member is to be placed. Alternatively, the main body is a flat tube.

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates to a fuel discharge member that is preferably used to reduce the amount of NOx exhaust, and a burner, a premixing nozzle of a combustor, a combustor, a gas turbine and a jet engine, which are equipped with this fuel discharge member.

2. Description of Related Art

[0002] A gas turbine and a jet engine each include a compressor, a combustor, and a turbine. The compressor and the turbine are connected to each other by means of a main shaft. The combustor is connected to an outlet of the compressor.

[0003] A working fluid gas is compressed by the compressor in order to supply a high-pressure gas to the combustor. The high-pressure gas is heated to a predetermined turbine inlet temperature by the combustor in order to supply a high-pressure and high-temperature gas to the turbine. The high-temperature and high-pressure gas is expanded in a cylinder of the turbine, as the high-temperature and high-pressure gas passes between a stator blade and a rotor blade disposed on the main shaft of the turbine. Thereby, the main shaft is rotated, so that a shaft output is generated. Since a shaft output can be obtained, wherein the consumption power of the compressor is excluded, the shaft output can be used as a driving source by connecting an electric power generator to the main shaft at the opposite side of the turbine, for example.

[0004] The jet engine uses the output in the form of kinetic energy of a high-velocity jet to directly propel an aircraft.

[0005] The development of the gas turbine and the jet engine described above has been promoted in order to reduce the emissions of NOx and the like, in view of recent environmental problems. Particularly, various research and development related to combustors has been undertaken and is disclosed in Japanese Unexamined Patent Application, First Publication No. Hei 8-54119, No. Hei 10-318541, No. Sho 60-126521, No. Hei 8-21627, No. Hei 9-119639, No. Hei 4-283316, and Japanese Examined Patent Application, Second Publication No. Hei 6-84817, for example.

[0006] In Japanese Unexamined Patent Application, First Publication No. Hei 8-21627, a fuel nozzle, which is used during the entire operation of a gas turbine to reduce emissions of air pollutants in exhaust gas of the gas turbine, is disclosed. In the following, the fuel nozzle is described with reference to FIG. 11.

[0007] This fuel nozzle includes a housing 1 and a central tube 2, and an annular chamber 3 is formed between the housing 1 and the central tube 2. Downstream

of the central tube 2, an inner swirler 4 and an outer swirler 5 are disposed so as to be connected to the downstream side of the annular chamber 3. Downstream of the inner swirler 4 and the outer swirler 5, a combustion area is provided.

[0008] In a diffusion combustion mode, when a fuel gas is supplied to the inner swirler 4 from an aperture 2a that is provided near the front end of the central tube 2, a portion of the air, which is supplied to the annular chamber 3, is mixed with the fuel gas by the inner swirler 4, so that diffusion flames are maintained in a diffusion mixing cup 6 disposed at the downstream side of the inner swirler 4. On the other hand, the remaining air which is supplied to the annular chamber 3, is led to the outer swirler 5 after being separated from the air which is supplied to the inner swirler 4, by means of a splitter vane which extends circumferentially to form the diffusion mixing cup 6. At the upstream portion of the annular chamber 3, a plurality of spokes 7 protrude toward the inside of the annular chamber 3. In a premixing combustion mode, the fuel gas is supplied to the annular chamber 3 from apertures 7a of the spokes 7, and is subsequently mixed with the air which is supplied to the annular chamber 3. At that time, the flow passage of the fuel gas, which communicates with the aperture 2a to supply the fuel gas to the inner swirler 4, is shut, and thereby, the entire fuel gas is supplied to the spokes 7. In FIG. 11, a fuel source 6 and a fuel gas passage switching valve 9 are also shown.

[0009] As described above, since the spokes 7 are disposed at the upstream side of the inner swirler 4 and the outer swirler 5, a fuel/air mixture in the premixing combustion mode is supplied to the inner swirler 4 and the outer swirler 5 from the annular chamber 3, and is accelerated to a high-velocity swirl through an aerodynamic vane. This high-velocity swirl prevents the flashback of combustion from the combustion zone into the annular chamber 3. Therefore, the surface of the premixing flame is stabilized, and the entirety of air which is supplied from the compressor is used so as to be mixed with the fuel gas which is supplied from the spokes 7. Therefore, a lean fuel/air ratio in the premixing combustion mode can be obtained, thereby reducing the amount of NOx exhaust in the mid to high-load operating range of the turbine.

[0010] However, in recent gas turbines and jet engines, the combustion temperature in the combustor tends to be set at a high temperature to improve the efficiency of the combustion. Even in the premixing combustion mode described above, since the range of the concentration distribution of the premixed fuel is broad due to the reasons described below, a rich zone, wherein the fuel concentration (fuel/air ratio) is greater than 1, is generated, so that NOx is generated in a high concentration in the rich zone. Thus, it is difficult to reduce the amount of NOx exhaust from the combustor.

[0011] Particularly, when the combustion temperature is raised to over approximately 1600°C, it is known that

the concentration of NO_x contained in the combustion gas is rapidly increased. Therefore, when the combustion temperature is set to become near 1600°C in order to increase the efficiency of the combustion, even if the range of the concentration distribution of the fuel is relatively narrow, NO_x may be easily generated. Therefore, it is desired to make the concentration of the premixed fuel uniform in order to improve efficiency of the gas turbine and the jet engine, and to reduce the NO_x exhaust at the same time.

[0012] In the following, the reasons why the range of the concentration distribution of the fuel is broad in the premixing combustion mode are described. In this case, the fuel gas is supplied from the apertures 7a of the spokes 7 of which a comparatively large cross-sectional area protrudes into the air flow passage. Thereby, downstream of the spokes 7, a negative pressure zone is generated in the flow direction of the air. Then, the air flow is engulfed by the negative pressure area, so that swirls are generated in the negative pressure area. Due to the generation of swirls, the fuel gas can be circumferentially supplied for a short time from the apertures 7a disposed perpendicular to the air flow passage, for example. That is, the fuel gas loses penetration force through the air flow. Therefore, the concentration distribution of the fuel gas becomes circumferentially nonuniform.

[0013] Japanese Unexamined Patent Application, First Publication No. Hei 8-21627, No. Hei 10-318541, and No. Hei 9-119639 disclose spokes protruding in the air flow passage and a device that supplies a fuel gas from an aperture of a hollow pole, for example. However, the concentration distribution cannot be made uniform according to these prior art publications.

SUMMARY OF THE INVENTION

[0014] The present invention has been made to solve the problems described above. An object of the present invention is to provide a fuel discharge member, which can be operated with high effectiveness by setting a high-temperature of the combustion, and to reduce the amount of NO_x exhaust at the same time, and is provided with a burner, a premixing nozzle, a combustor, a gas turbine, and a jet engine.

[0015] In order to achieve the object described above, the present invention utilizes the following constitution.

[0016] A fuel discharge member according to the present invention includes a main body to be fixed on a fuel supply conduit. The fuel discharge member includes a main body which has an internal space that communicates with a fuel passage in the fuel supply conduit, fuel discharge outlets which communicated with the internal space, and a trailing edge. The thickness of the trailing edge may be no more than 5 mm, or a flow passage block ratio of the fuel discharge member may be no more than 10% of the cross-sectional area of the air flow passage in which the fuel discharge member is to be placed.

[0017] By the use of this fuel discharge member, since the thickness of the trailing edge is thin enough such that the flow passage block ratio of the fuel discharge member is no more than 10%, the effective area of the air flow passage is enlarged, so that the generation of swirls is suppressed at the downstream side of the fuel discharge member with respect to the air flow.

[0018] Alternatively, the main body of the fuel discharge member may be a flat tube. By the use of this fuel discharge member, since the projected area of the main body in the air flow direction is decreased, the effective area of the air flow passage is increased, so that the generation of swirls is suppressed at the downstream side of the fuel discharge member with respect to the air flow.

[0019] The fuel discharge member may be disposed so that the fuel discharge outlets of the main body open the perpendicular or approximately perpendicular to the air flow passage. In this case, the fuel is discharged by a strong penetration force through the air flow in which the generation of swirls is suppressed at downstream side of the fuel discharge member.

[0020] In the fuel discharge member, the trailing edge of the main body may be inclined so that the base end of the trailing edge extends further downstream from the tip end of the trailing edge with respect to the air flow—which is to be formed in the air flow passage. Thereby, the air flows in a radially outward direction along the trailing edge, so that the generation of a second flow, which may cause the generation of swirls, is suppressed. In this case, the trailing edge may be formed with a detachable inclined member. Thus, the fuel discharge member of which the trailing edge is inclined can be easily manufactured.

[0021] In the fuel discharge member, the fuel discharge outlets may be disposed axially in a plurality of lines at radially staggered positions on both sides of the main body. Thereby, the fuel flow discharged from the respective fuel discharge outlets can be made uniform.

[0022] In the fuel discharge member, the fuel discharge outlets may open toward the downstream direction so as to discharge the fuel in the downstream direction of the fuel discharge member with respect to the air flow. By the use of this fuel discharge member, it is possible to make the concentration distribution of the fuel uniform.

[0023] The cross-sectional shape of the fuel discharge member may be an elliptical shape, a flat oval shape, or an annular shape. The trailing edge may be formed with a protruding portion at the downstream side with respect to the air flow.

[0024] A burner according to the present invention includes a fuel supply conduit in which a fuel passage is formed so as to communicate with a fuel supply source; the fuel discharge member described above; and swirlers which are fixed on the fuel supply conduit so as to rotate an air flow or a premixed gas flow containing air and fuel.

[0025] A plurality of fuel discharge members may be arranged axially in a plurality of lines on the fuel supply conduit. Thereby, the number of fuel discharge outlets can be increased without decreasing the effective area of the air flow passage.

[0026] The fuel discharge members may be disposed so that the fuel discharge members are circumferentially displaced in relation to one another. In this case, the circumferential concentration distribution of the fuel can be made uniform.

[0027] The swirlers may be disposed downstream of the fuel discharge member with respect to the air flow. The swirler and the fuel discharge member may be arranged circumferentially in the same line. In this case, since the turbulence of the flow velocities caused by the fuel discharge member interacts with the turbulence of the flow velocities caused by the swirler, the turbulence of the flow velocities caused by the fuel discharge member downstream thereof can be prevented.

[0028] Alternatively, the swirlers may be disposed so that the swirler and the fuel discharge member are circumferentially staggered with respect to each other. In this case, since the turbulence of the flow velocities are generated respectively downstream of the fuel discharge member and the swirler, the turbulence of the flow velocities are made approximately uniform downstream of the swirler.

[0029] The fuel supply conduit may further comprise a liquid fuel passage which communicates with a liquid fuel supply source, and fuel discharge holes which communicate with the liquid fuel passage substantially at the tip end portions of the fuel supply conduit.

[0030] This burner suppresses the generation of swirls downstream of the fuel discharge member, so that the concentration distribution of the fuel can be made uniform. Thus, since the amount of fuel burned at a high fuel/air ratio, which causes an increase in the amount of NOx exhaust, is reduced, the amount of NOx exhaust can be reduced.

[0031] A premixing nozzle of the combustor according to the present invention has a pilot burner which is disposed on the central axis of the premixing nozzle, and also has the burners described above which are disposed as main burners surrounding the pilot burner.

[0032] Since the premixing nozzle of the combustor is provided with the burners which suppress the generation of swirls downstream of the fuel discharge member, it is possible to make the concentration distribution of the fuel uniform. Therefore, the amount of fuel burned at a high fuel/air ratio, which causes an increase in the amount of NOx, exhaust is reduced, and the amount of NOx exhaust is reduced.

[0033] A combustor of the present invention has the premixing nozzle described above, and a cylinder which holds the premixing nozzle therein.

[0034] Since this combustor includes the premixing nozzle which can suppress the generation of swirls downstream of the fuel discharge member, it is possible

to make the concentration distribution of the fuel uniform. Thereby, the amount of fuel burned at a high fuel/air ratio, which causes an increase in the amount of NOx exhaust, is reduced, and the amount of NOx exhaust is reduced.

[0035] A gas turbine of the present invention comprises a compressor which compresses air to generate a high-pressure gas; the combustor described above, which is connected to the compressor so as to be supplied with the high-pressure gas from the compressor, and which heats the high-pressure gas to generate a high-temperature and high-pressure gas; and a turbine which is connected to the combustor so as to be supplied with the high-temperature and high-pressure gas from the combustor, and which rotates an out shaft by expanding the high-temperature and high-pressure gas to generate a shaft output.

[0036] Since this gas turbine includes the combustor which can suppress the generation of swirls downstream of the fuel discharge member, it is possible to make the concentration distribution of the fuel uniform. Thereby, the amount of fuel burned at a high fuel/air ratio, which causes an increase in the amount of NOx exhaust, is reduced, and the amount of NOx exhaust is reduced.

[0037] A jet engine of this present invention comprises a compressor which compresses air to generate a high-pressure gas, the combustor described above, which is connected to the compressor so as to be supplied with the high-pressure gas from the compressor, and which heats the high-pressure gas to generate a high-temperature and high-pressure gas, and the turbine which is connected to the combustor so as to be supplied with the high-temperature and high-pressure gas from the combustor.

[0038] Since this jet engine includes the combustor which can suppress the generation of swirls downstream of the fuel discharge member, it is possible to make the concentration distribution of the fuel uniform. Thereby, the amount of fuel burned at a high fuel/air ratio, which causes an increase in the amount of NOx exhaust, is reduced, and the amount of NOx exhaust is reduced.

BRIEF DESCRIPTION OF DRAWINGS

[0039]

FIGS. 1A to 1C show a burner comprising a fuel discharge member of a first embodiment according to the present invention: FIG. 1A is a cross-sectional view of a key portion of the burner; FIG. 1B is a cross-sectional view of the fuel discharge member taken along the line A-A of FIG. 1A; and FIG. 1C is a cross-sectional view of the burner taken along the line B-B of FIG. 1A.

FIG. 2 is a graph which shows the relationship between the flow passage block ratio of a fuel dis-

charge member and the NO_x concentration.

FIGS. 3A to 3E show respective modified cross-sectional shapes of the fuel discharge member of a first embodiment according to the present invention: FIG. 3A is a cross-sectional view of a first modification; FIG. 3B is a cross-sectional view of a second modification; FIG. 3C is a cross-sectional view of a third modification; FIG. 3D is a cross-sectional view of a fourth modification, and FIG. 3E is a cross-sectional view of a fifth modification.

FIG. 4A is a cross-sectional view of a key portion of a burner comprising a fuel discharge member of a second embodiment according to the present invention. FIG. 4B is a cross-sectional view of the fuel discharge member, which is taken along the line C-C of FIG. 4A.

FIGS. 5A and 5B show a modified fuel discharge member according to the present invention: FIG. 5A is a cross-sectional view, and FIG. 5B is a cross-sectional view taken along the line D-D of FIG. 5A. FIG. 6 is a schematic representation which illustrates the action of the second embodiment shown in FIG. 4A.

FIGS. 7A and 7B show a fuel discharge member of a third embodiment according to the present invention: FIG. 7A is a cross-sectional view of a key portion of the fuel discharge member, and FIG. 7B is a cross-sectional view taken along the line E-E of FIG. 7A.

FIGS. 8A and 8B show the relationship between the fuel discharge member and swirlers of a fourth embodiment according to the present invention: FIG. 8A is a schematic representation which illustrates the relationship between the fuel discharge member and the main swirlers, wherein the fuel discharge member and the main swirlers are staggered; and FIG. 8B is a schematic representation which illustrates the relationship between the fuel discharge member and the main swirlers, wherein the fuel discharge member and one main swirler are arranged in the same line.

FIG. 9 is a cross-sectional view which shows a burner according to a fifth embodiment of the present invention.

FIGS. 10A and 10B show a combustor including a fuel discharge member of the present invention: FIG. 10A is a cross-sectional view of a key portion of the combustor, and FIG. 10B is a cross-sectional view of FIG. 10A.

FIG. 11 is a cross-sectional view which shows a combustor according to the prior art.

DETAILED DESCRIPTION OF THE INVENTION

[0040] In the following, embodiments according to the present invention will be explained with reference to the drawings.

FIRST EMBODIMENT

[0041] A gas turbine expands a high-temperature and high-pressure gas in the turbine and rotates the main shaft to generate a shaft output which is used as a driving force for an electric power generator and the like. A jet engine expands the high-temperature and high-pressure gas in the turbine and rotates the main shaft to exert kinetic energy of a high-velocity jet (exhaust), discharged from an outlet of the turbine, as a propelling force of an aircraft.

[0042] The main components of the gas turbine and the jet engine are a compressor, a combustor, and a turbine.

[0043] The compressor compresses a gas, that is air, which is introduced from an inlet thereof, as a working fluid in order to supply a high-pressure gas to the combustor that is connected to the outlet of the compressor. This compressor used is an axial compressor which is connected to the turbine through the main shaft. In the combustor, the high-pressure gas is burned to generate a high-temperature and high-pressure. Then, the high-temperature and high-pressure gas is supplied to the turbine.

[0044] In the following, the combustor according to a first embodiment is described with reference to FIGS. 10A and 10B.

[0045] A combustor 10 is equipped with a premixing nozzle 12 along a central axis of an internal cylinder 11. The internal cylinder 11 is a circular cylinder of which both ends open. The premixing nozzle 12 includes a pilot burner 13 and a plurality of main burners 14. The pilot burner 13 is provided at the central position which coincides with the central axis of the premixing nozzle 12. The plurality of main burners 14 are disposed at even intervals so as to surround the pilot burner 13. Therefore, the central axis of the pilot burner 13 is the central axis of the internal cylinder 11. In FIG. 10B, eight main burners 14 are disposed so as to surround the pilot burner 13, wherein the main burners 14 each have the same form.

[0046] The pilot burner 13 of the premixing nozzle 12 includes a pilot fuel tube 15 and pilot swirlers 16. The pilot fuel tube 15 is a circular cylinder of which one end is connected to a fuel supply source which is not shown, so that pilot fuel is supplied to the pilot fuel tube 15 from the fuel supply source. At the other end of the pilot fuel tube 15, a pilot fuel nozzle 15a is formed so as to open toward a combustion chamber 10a of the combustor 10 which is formed on the internal cylinder 11. Thus, the pilot fuel is supplied to the combustion chamber 10a from the pilot fuel nozzle 15a. The pilot swirlers 16 have a twisted shape, and are fixed on the pilot fuel tube 15 at even intervals in the circumferential direction. In FIG. 10B, the pilot swirlers 16 are disposed on the pilot fuel tube 15 at intervals of 45° in the circumferential direction. The pilot swirlers 16 give a swirling motion to the air flow (shown by an arrow) which passes through the

pilot swirlers 16. Thereby, the air flow is emitted to the surroundings of the pilot fuel nozzle 15a.

[0047] The pilot fuel supplied from the pilot fuel nozzle 15a burns the swirled flow of air as combustion gas to generate flames in the combustion chamber 10a. Thus, flames generated by the pilot burners 13 are used to generate flames at the main burner 14.

[0048] The main burner 14 of the premixing nozzle 12 includes a fuel supply conduit 17, fuel discharge members 20, and swirlers 18. The fuel supply conduit 17 is a circular cylinder in which a fuel passage is formed. One end of the fuel supply conduit 17 is connected to a fuel supply source, which is not shown, in order to supply main fuel to the fuel supply conduit 17. The other end of the fuel supply conduit 17 is closed. The fuel discharge members 20 are fixed on the fuel supply conduit 17 at even intervals in the circumferential direction. The fuel discharge member 20 includes a main body having an internal space which communicates with the fuel supply conduit 17, and fuel discharge outlets 21 which communicate with the internal space, so as to discharge the main fuel into the air flow. The swirlers 18 have a twisted shape, and are fixed on the fuel supply conduit 17 at even intervals in the circumferential direction. In FIG. 10B, the swirlers 18 are disposed on the fuel supply conduit 17 at intervals of 45° in the circumferential direction. The swirlers 18 are disposed downstream of the fuel discharge members 20. The swirlers 18 give a swirling motion to the air flow passing at the peripheral portion of the fuel supply conduit 17. In FIG. 10B, eight main burners 14 contact each other and surround the pilot burner 13.

[0049] Thus, the main burners 14 discharge the main fuel gas, which is introduced through the fuel supply conduit 17 to a fuel discharge outlet 21, into the air flow from the fuel discharge outlet 21. Thereby, the fuel gas and the air are premixed, so that a premixed gas is generated. When the premixed gas passes through the swirlers 18, the premixed gas is swirled by the swirlers 18, and subsequently emitted to the combustion chamber 10a of the combustor 10. The premixed gas is led to the surroundings of the pilot burner 13 from the eight main burners 14 in the combustion chamber 10a. The premixed gas is ignited by the flames generated by the pilot burner 13 described above, so that a high-temperature gas is generated. The generated gas is emitted from an aperture which is disposed at one end of the internal cylinder 11.

[0050] An external cylinder 19 is disposed on the outer side of the internal cylinder 11. The external cylinder 19 is a circular cylinder of which one end is opened. At the other end of the external cylinder 19, an introductory passage of the air flow is formed so as to reverse the air flow direction.

[0051] In the following, the burner used as the main burner 14 according to the first embodiment will be explained in further detail.

[0052] FIG. 1A shows the burner including the fuel

supply conduit 17, the fuel discharge members 20, and the swirlers 18. The fuel discharge member 20 includes the main burner 14, the fuel supply conduit 17, the swirlers 18, and the fuel discharge outlets 21.

[0053] As shown in FIG. 1A, the fuel discharge members 20 are fixed on the fuel supply conduit 17 and radially protrude into the air flow passage (shown by an arrow). The fuel discharge member 20 includes a main body 23 having an internal space 22, fuel discharge outlets 21, and a trailing edge 23a. The tip end of the main body 23 is closed, and the base end of the main body 23 communicates with the fuel passage in the fuel supply conduit 17 through the internal space 22. The internal space 22 is formed so as to communicate with the fuel passage in the fuel supply conduit 17 at the base end of the internal space 22. In FIG. 1A, two fuel discharge outlets 21 are centrally aligned at opposite sides of the main body 23, respectively. The fuel discharge outlets 21 open toward a perpendicular or almost perpendicular direction to the air flow passage. The fuel discharge outlets 21 are formed so as to communicate with the internal space 22. However, the number of fuel discharge outlets 21 formed in the main body 23 is not limited to two, and the relationship between the fuel discharge outlets 21 is also not limited such that they are aligned.

[0054] In FIG. 1B, the main body 23 used is a flat tube of which the cross-sectional shape is a flat oval shape. The flat oval shape has two opposite linear portions disposed parallel to each other and both tip ends of the opposite linear portions are connected to each other forming semicircular portions, as shown in FIG. 1B. The thickness t of the main body 23 in a direction perpendicular to the air flow passage is set to be no more than 5 mm or to be thin enough such that the flow passage block ratio thereof (the ratio of the cross-sectional area, wherein the trailing edge 23a of the fuel discharge member 23 occupies the air flow passage, to the total cross-sectional area of the air flow passage) is no more than 10%. As a result, the thickness of the trailing edge 23a of the main body 23 becomes thin.

[0055] In FIG. 1C, four fuel discharge members 20 are disposed at intervals of 90° in the circumferential direction. The swirlers 18 are disposed at intervals of 45° in the circumferential direction downstream of the fuel discharge members 20, with respect to the flow of the air. The swirlers 18 have a twisted shape.

[0056] As described above, since the thickness t of the trailing edge 23a of the main body 23 is set to be no more than 5 mm or to be thin enough such that the flow passage block ratio thereof is no more than 10%, an interrupted effective area of the air flow passage, wherein the air flow is interrupted by the fuel discharge member 20 fixed on the fuel supply conduit, is decreased, so that the flow of the premixed gas is made uniform. Thus, a negative pressure area, caused by the interruption of the flow of the premixed gas by the fuel discharge member 20 and formed downstream of the trailing edge 23a,

is decreased, so that the generation of swirls caused by the negative pressure area, wherein the air flow is entrained, is reduced.

[0057] Thereby, the turbulence of the velocity distribution of the air flow is decreased at the downstream side of the fuel discharge member 20. Thus, since the penetration force of the fuel gas discharged from the fuel discharge outlet 21 can be maintained approximately constantly, the concentration distribution of the fuel gas in the premixed gas can be constantly maintained in spite of the quality or the quantity of the fuel gas in the premixed gas.

[0058] Since four fuel discharge members 20 are disposed at intervals of 90° in the circumferential direction and the plurality of fuel discharge outlets 21 are disposed respectively on both sides of the fuel discharge members 20, the circumferential concentration distribution of the fuel gas is made uniform. Moreover, since two fuel discharge outlets 21 are disposed radially in a line on the opposite sides of the fuel discharge member 20, the radial concentration distribution of the fuel gas is made uniform. The number of fuel discharge members 20 and the arrangement of the fuel discharge members 20 may be suitably decided.

[0059] In FIG. 2, experimental results show the relationship between the flow passage block ratio of the fuel discharge members 20 and the concentration of NOx exhausted. When the flow passage block ratio of the fuel discharge members 20 is increased, the concentration of NOx exhausted is also increased.

[0060] In the United States, the concentration of NOx exhausted is restricted to be no greater than 25 ppm. According to the experimental results shown in FIG. 2, the flow passage block ratio of the fuel discharge members 20 may be set to no more than 10 % to satisfy the restriction of the concentration described above. When the flow passage block ratio of the fuel discharge members 20 is set to 7%, the concentration of NOx exhausted is 9 ppm.

[0061] The cross-sectional shape of the main body 23 described above may be another modified shape other than the flat oval shape shown in FIG. 1B.

[0062] In a first modification shown in FIG. 3A, a flat tube, wherein the cross-sectional shape is a flat oval shape, is used, and two fuel discharge outlets 21 are disposed on both sides and staggered with respect to each other in the direction of the air flow, that is, in the axial direction of the fuel supply conduit 17. Thus, interaction between the fuel discharge outlets 21 can be reduced, so that the fuel gas is constantly supplied.

[0063] In a second modification shown in FIG. 3B, a flat tube, wherein the cross-sectional shape is an elliptical shape, is used, and the opposite sides in which the fuel discharge outlets 21 are disposed, are curved.

[0064] In a third modification shown in FIG. 3C, the trailing edge 23a is formed with a protruding portion 24 disposed on the end of the trailing edge side of the first modification. In this case, the protruding portion 24 may

be formed into a semicircle of which the radius R is small enough so that the thickness t of the trailing edge 23a is no more than 5 mm or the flow passage block ratio of the fuel discharge member is no more than 10% with respect to the cross-sectional area of the air flow passage in which the fuel discharge member 20 is to be placed. Thereby, the internal space 22 of the main body 23 has a large cross-sectional shape, so that a large flow of the fuel gas can be easily maintained. Moreover, the generation of swirls at the downstream side is prevented, so that the fuel concentration distribution can be made uniform.

[0065] In a fourth modification shown in FIG. 3D, protruding portions 24 and 25 are disposed at opposite sides to form the trailing edge 23a and a leading edge of the fuel discharge member 20 according to the second modification, and thereby, the generation of swirls downstream of the fuel discharge member 20 is satisfactorily prevented. These protruding portions 24 and 25 may be disposed in another type of fuel discharge member of which the cross-sectional shape is a flat oval shape or a circular shape, for example.

[0066] In a fifth modification shown in FIG. 3E, the trailing edge 23a is thin enough such that the thickness of the trailing edge 23a is no more than 5 mm or the flow passage block ratio of the fuel discharge member 20 is no more than 10% ($R < 2.5$ mm). The cross-sectional shape of the main body 23 is a wing shape, and the cross-sectional shape of the internal space 22 is an elliptical shape. In this case, the generation of swirls is suppressed as described above.

[0067] The cross-sectional shape of the internal space 22 is not limited to an elliptical shape, and may be a flat oval shape or an annular shape.

SECOND EMBODIMENT

[0068] In the following, a burner including a fuel supply conduit 17, a fuel discharge member 30, and swirlers 18 of the second embodiment will be explained with reference to FIGS. 4A. and 4B. In this case, the same members as those of the first embodiment are indicated by the same reference numbers, and descriptions of the same members are omitted.

[0069] In FIG. 4A, fuel discharge members 30 and swirlers 18 are fixed on the fuel supply conduit 17.

[0070] The fuel discharge member 30 including a main body 33 having fuel discharge outlets 31, an internal space 32, and a trailing edge 33a is shown. In this embodiment, the trailing edge 33a is inclined so that the base end of the trailing edge 33a extends further downstream from the tip end of the trailing edge 33a with respect to the air flow which is to be formed in the air flow passage. That is, the shape of the fuel discharge member 30 as viewed from the side is a tail assembly shape.

[0071] The internal space 32 communicates with the fuel passage in the fuel supply conduit 17 at the base end of the internal space 32. In the main body 33, the

fuel discharge outlets 31 open toward a direction perpendicular to the air flow passage and communicate with the internal space 32. In FIG. 4A, on the opposite sides of the main body 33, two fuel discharge outlets 31 are arranged along an angular line with respect to the air flow and are staggered axially with respect to each other. Thus, four fuel discharge outlets 31 are disposed on the respective main bodies 33 so as to be axially displaced in relation to one another.

[0072] In this case, the main body 33 used is a flat tube wherein the cross-sectional shape is a flat oval shape of which both opposite sides are parallel to each other and both tip ends are connected to each other forming a curve, as shown in FIG. 4B. The thickness t of the main body 33 in a direction perpendicular to the air flow passage is set to be no more than 5 mm or to be thin enough such that the flow passage block ratio of the fuel discharge member is no more than 10% with respect to the cross-sectional area of the air flow passage in which the fuel discharge member 20 is to be placed. In this case, the thickness of the trailing edge 33a of the main body 33 becomes thin.

[0073] In FIG. 4A, four fuel discharge members 30 are disposed at intervals of 90° in the circumferential direction and protrude radially, and swirlers 18 are disposed at intervals of 45° in the circumferential direction downstream of the fuel discharge members 30 with respect to the air flow.

[0074] The cross-sectional shape of the main body 33 is not limited to the flat oval shape described above, and may be the cross-sectional shapes shown in FIGS. 3A to 3E, respectively.

[0075] As shown in FIG. 5A, the trailing edge 33a may be formed with a detachable inclined member 34 of which the lateral shape is a triangle, so that the trailing edge 33a is inclined. This construction makes it easy to manufacture the fuel discharge member 30 of which the trailing edge 33a is inclined.

[0076] In the following, the effects of the fuel discharge member 30, of which trailing edge 33a is inclined, will be explained with reference to FIG. 6.

[0077] In general, a negative pressure area is formed downstream of the fuel discharge member 33, and thereby, the air flow is swirled. In contrast, when the trailing edge 33a of the fuel discharge member 30 is inclined as shown in FIG. 6, the air flows from the base end of the fuel discharge member 30 along the incline of the trailing edge 33a, so that the air flow is prevented from being swirled. Thus, the concentration distribution of the fuel gas can be made uniform.

[0078] Since the fuel discharge member 30 is a flat tube, the fuel discharge outlets 31 are staggered axially. That is, one of the fuel discharge outlets 31, positioned axially upstream with respect to the air flow, is disposed near the tip end of the fuel discharge member 30. The other of the fuel discharge outlets 31, positioned axially downstream with respect to the air flow, is arranged near the base end of the fuel discharge member 30. The fuel

gas can be uniformly discharged from both fuel discharge outlets 31 which are axially staggered. Therefore, even if the number of fuel discharge outlets 31 is increased, the radial penetration force is made uniform.

Moreover, the radial concentration distribution of the fuel gas can be made uniform by inclining the trailing edge 33a as described above. The circumferential concentration distribution can be easily made uniform by increasing the number of fuel discharge members 30 and fuel discharge outlets 31.

THIRD EMBODIMENT

[0079] In the third embodiment, the fuel discharge members 30 are disposed on the fuel supply conduit 17 in a plurality of lines along the axial direction of the fuel supply conduit 17 (along the flow direction of the air). In FIG. 7A, the fuel discharge members 30 are axially arranged in two lines.

[0080] In this case, a fuel discharge member 30A located upstream and a fuel discharge member 30B located downstream may be arranged at the same position circumferentially and protrude radially. Alternatively, the fuel discharge members 30A and 30B may be staggered circumferentially as shown in FIG. 7B.

[0081] When the plurality of fuel discharge members 30 are respectively arranged at the same positions circumferentially as described above, the effective area of the air flow passage in which the plurality of fuel discharge members 30 are to be placed hardly changes compared to the effective area in which only one fuel discharge member 30 is to be placed. Therefore, the number of fuel discharge outlets 31 to be disposed can be increased while maintaining the effective area of the air flow passage, and the circumferential concentration distribution of the fuel gas can be made uniform.

[0082] When the plurality of fuel discharge members 30 are staggered circumferentially, the interval which circumferentially separates the fuel discharge outlets 31 from each other becomes small, in accordance with the increase in the number of fuel discharge outlets 31. Therefore, the circumferential concentration distribution of the fuel gas can be made more uniform.

FOURTH EMBODIMENT

[0083] In the fourth embodiment shown in FIGS. 8A and 8B, the relationship between the fuel discharge member 30 and the swirlers 18 is described.

[0084] In FIG. 8A, the fuel discharge member 30 and the swirlers 18 are staggered circumferentially. That is, the fuel discharge member 30 is disposed upstream of a position which is located between the adjacent swirlers 18. In this case, the intensity of the turbulence of flow velocity v' is enlarged in accordance with the proximity to the fuel discharge member 30, as shown in FIG. 8A. The fuel gas is engulfed in swirls generated at downstream of the fuel discharge member 30, so that the fuel

gas becomes concentrated. In contrast, the intensity of the turbulence of flow velocity v'' is generated downstream of the swirlers 18, as shown in FIG. 8A. The turbulence of flow velocity v'' interacts with the turbulence of flow velocity v' , so that the distribution of the turbulence of the flow velocity becomes uniform at downstream of the swirlers 18. Then, a premixed gas, wherein the fuel gas is discharged into the air, is mixed by this uniform turbulence of the flow velocity, so that the concentration distribution of the fuel gas becomes uniform.

[0085] In FIG. 8B, the fuel discharge member 30 and one of the swirlers 18 are aligned circumferentially. That is, the fuel discharge member 30 is located circumferentially upstream of the swirlers 18. In this case, positions of the turbulence of flow velocity v' caused by the fuel discharge member 30 and the turbulence of flow velocity v'' caused by the swirlers 18 are circumferentially consistent with each other, so that effects caused by the fuel discharge member 30 at the downstream side can be suppressed. That is, the turbulence of the flow velocity caused by the fuel discharge member 30 is substantially negligible.

FIFTH EMBODIMENT

[0086] In FIG. 9, a burner 14A including a fuel supply conduit 40, fuel discharge members 30, and swirlers 18 according to the fifth embodiment is shown. In the fuel supply conduit 40, a fuel passage (not shown), a liquid fuel passage (not shown), and fuel discharge outlets 41 are formed. The fuel passage is formed so as to communicate with a fuel gas supply source to supply the fuel gas to the fuel discharge members 30. The liquid fuel passage is formed so as to communicate with a liquid fuel supply source to supply liquid fuel to the fuel discharge outlets 41. The fuel discharge outlets 41 are formed so as to communicate with the liquid fuel passage substantially at the tip end portions of the fuel supply conduit 40. The fuel discharge outlets 41 open toward the downstream direction of the swirlers 18 with respect to the air flow.

[0087] By the use of this burner 14A, premixed gas, wherein the concentration of the fuel gas is uniform, can be formed in the same manner as described above.

[0088] As described above, by using the fuel discharge member 20 or 30, the concentration distribution of the fuel gas in the premixed gas, wherein air and fuel gas are mixed, can be made circumferentially and radially uniform, so that the area, wherein the concentration of the fuel gas is high, that is, the fuel/air ratio is over 1, can be reduced.

[0089] When the concentration distribution of the fuel gas is made uniform, even if the temperature for the combustion is raised to near 1600°C, the amount of NOx generated during the combustion can be reduced. Thus, by using a burner having a fuel discharge member, a premixing nozzle having a burner, and a combustor having a premixing nozzle, the total amount of NOx gener-

ated can be reduced. Moreover, a gas turbine and a jet engine, which include a burner, a premixing nozzle, and a combustor, can reduce the amount of NOx generated, even if the temperature for the combustion is raised to operate with high effectiveness. Particularly, when the trailing edge of the fuel discharge member 20 or 30 is set to be thin enough such that the thickness thereof is no more than 5 mm or the flow passage block ratio of the fuel discharge member is no more than 10% with respect to the cross-sectional area of the air flow passage in which the fuel discharge member is to be placed, the generation of NOx can be considerably reduced.

[0090] Although the fuel discharge outlets 21 and 31 are respectively disposed in the fuel discharge members 20 and 30 perpendicular or approximately perpendicular to the air flow passage, the fuel discharge outlets according to the present invention may be disposed downstream of the fuel discharge members with respect to the direction of the air flow.

[0091] Although the swirlers 18 are preferably disposed downstream of the fuel discharge members 20 or 30, the swirlers may be disposed upstream of the fuel discharge members.

[0092] Although the fuel discharge members are disposed in the main burner of the premixing nozzle in the respective embodiments described above, the fuel discharge members may be disposed in a pilot burner.

[0093] Although the combustor 10, the premixing nozzle 12, the main burner 14, the gas turbine, and the jet engine include the fuel discharge member according to the present invention, configurations of the combustor 10, the premixing nozzle 12, the main burner 14, the gas turbine, and the jet engine are not limited to the configurations described in the respective embodiments. That is, the number of pilot burners 13 and main burners 14 disposed in the premixing nozzle 12 or the number of fuel discharge members protruding from the main burner 14 may be suitably selected, for example.

[0094] It is understood, by those skilled in the art, that the foregoing description is a preferred embodiment of the disclosed configurations and that various changes and modifications may be made to the invention without departing from the spirit and scope thereof.

[0095] The following effects can be obtained by the present invention.

[0096] By using the fuel discharge member of which the thickness at the trailing edge is no more than 5 mm or the flow passage block ratio of the fuel discharge member is no more than 10% with respect to the cross-sectional area of the air flow passage in which the fuel discharge member is to be placed, the generation of swirls downstream of the fuel discharge member is reduced, so that the concentration distribution of the premixed gas including air and fuel is made uniform. Therefore, the total amount of NOx exhaust can be reduced, even if the temperature for the combustion is raised.

[0097] By using a flat tube as the fuel discharge mem-

ber, the generation of swirls downstream of the fuel discharge member is reduced, so that the concentration distribution of the premixed gas including air and fuel is made uniform. Moreover, the number of fuel discharge outlets can be increased, and the fuel discharge outlets can be suitably disposed. Thereby, the concentration distribution can be made radially and circumferentially uniform.

[0098] By using the burner, the premixing nozzle, and the combustor, the concentration distribution of the premixed gas including air and fuel is made uniform. Therefore, the total amount of NOx exhaust can be reduced, even if the temperature for the combustion is raised.

[0099] By using the gas turbine or the jet engine, since the concentration distribution of the premixed gas is uniformly maintained, the total amount of NOx exhaust can be reduced, even if the temperature for the combustion is raised. Thus, highly effective operation and the reduction of the amount of NOx exhaust can be achieved at the same time.

Claims

1. A fuel discharge member to be fixed on a fuel supply conduit (17), comprising:
a main body (23) having an internal space (22) which communicates with a fuel passage in the fuel supply conduit; fuel discharge outlets (21) which communicates with the internal space; and a trailing edge (23a),
wherein the thickness (t) of the trailing edge (23a) is no more than 5 mm, or a flow passage block ratio of the fuel discharge member is no more than 10% with respect to the cross-sectional area of the air flow passage in which the fuel discharge member is to be placed.
2. A fuel discharge member according to claim 1, wherein the fuel discharge outlets (21) open toward a substantially perpendicular direction to the air flow passage.
3. A fuel discharge member according to claim 1, wherein the trailing edge (23a) of the main body (23) is inclined so that the base end of the trailing edge extends further downstream from the tip end of the trailing edge with respect to the air flow which is to be formed in the air flow passage.
4. A fuel discharge member according to claim 3, further comprising a detachable inclined member, which forms the trailing edge.
5. A fuel discharge member according to claim 1, wherein the fuel discharge outlets (21) are axially arranged in a plurality of lines and radially stag-

gered on the main body (23).

6. A fuel discharge member according to claim 1, wherein the fuel discharge outlets (21) open toward the downstream direction with respect to the air flow.
7. A fuel discharge member according to claim 1, wherein the cross-sectional shape of the main body (23) is a flat oval shape, an elliptical shape, or an annular shape, and the trailing edge (23a) is formed with a protruding portion (24, 25) at the downstream side with respect to the air flow.
8. A fuel discharge member to be fixed on a fuel supply conduit (17), comprising:
a main body (33) having an internal space (32) which communicates with a fuel passage in the fuel supply conduit; fuel discharge outlets (31) which communicate with the internal space; and a trailing edge (33a),
wherein the main body is a flat tube.
9. A fuel discharge member according to claim 8, wherein the fuel discharge outlets (31) open toward a substantially perpendicular direction to the air flow passage.
10. A fuel discharge member according to claim 8, wherein the trailing edge (33a) of the main body (33) is inclined so that the base end of the trailing edge extends further downstream from the tip end of the trailing edge with respect to the air flow which is to be formed in the air flow passage.
11. A fuel discharge member according to claim 10, further comprising a detachable inclined member, which forms the trailing edge.
12. A fuel discharge member according to claim 8, wherein the fuel discharge outlets (31) are axially arranged in a plurality of lines and radially staggered on the main body.
13. A fuel discharge member according to claim 8, wherein the fuel discharge outlets (31) open toward the downstream direction with respect to the air flow.
14. A fuel discharge member according to claim 8, wherein the flat tube has a cross-sectional shape of a flat oval shape or an elliptical shape.
15. A burner comprising:
a fuel supply conduit (17) in which a fuel passage is formed which communicates with a fuel supply source;

- a fuel discharge member (20) according to claim 1; and
swirlers (18) which are fixed on the fuel supply conduit (17) so as to rotate an air flow or a premixed gas flow containing air and fuel. 5
- 16.** A burner according to claim 15, wherein the fuel discharge members (20) are arranged axially in a plurality of lines. 10
- 17.** A burner according to claim 16, wherein the fuel discharge members (20) are so disposed so as to be circumferentially displaced with respect to each other. 15
- 18.** A burner according to claim 15, wherein the swirlers are disposed downstream of the fuel discharge members (20) with respect to the air flow, and are circumferentially aligned with the fuel discharge members. 20
- 19.** A burner according to claim 15, wherein the swirlers (18) are disposed downstream of the fuel discharge members (20) with respect to the air flow, and the swirlers and the fuel discharge members are circumferentially staggered with respect to each other. 25
- 20.** A burner according to claim 15, wherein the fuel supply conduit (17) further comprises: a liquid fuel passage which communicates with a liquid fuel supply source; and fuel discharge outlets which communicate with the liquid fuel passage substantially at the tip end portions of the fuel supply conduit. 30
- 21.** A burner comprising: 35
- a fuel supply conduit (17) in which a fuel passage is formed which communicates with a fuel supply source;
- a fuel discharge member (30) according to claim 8; and 40
- swirlers (18) which are fixed on the fuel supply conduit so as to rotate an air flow or a premixed gas flow containing a air and fuel. 45
- 22.** A burner according to claim 21, wherein the fuel discharge members (30) are arranged axially in a plurality of lines.
- 23.** A burner according to claim 22, wherein the fuel discharge members (30) are so disposed so as to circumferentially displaced with respect to each other. 50
- 24.** A burner according to claim 21, wherein the swirlers (18) are disposed downstream of the fuel discharge members (30) with respect to the air flow, and are circumferentially aligned with the fuel discharge members. 55
- 25.** A burner according to claim 21, wherein the swirlers (18) are disposed at downstream of the fuel discharge members (30) with respect to the air flow, and the swirlers and the fuel discharge members are circumferentially staggered with respect to each other.
- 26.** A burner according to claim 21, wherein the fuel supply conduit (17) further comprises: a liquid fuel passage which communicates with a liquid fuel supply source; and fuel discharge outlets (31) which communicate with the liquid fuel passage substantially at the tip end portions of the fuel supply conduit.
- 27.** A premixing nozzle of a combustor, comprising:
- a pilot burner (13) disposed on a central axis of the premixing nozzle; and
- a plurality of burners (14) according to claim 15 or 20, which are disposed as main burners surrounding the pilot burner (13).
- 28.** A combustor comprising:
- a premixing nozzle (12) according to claim 27; and
- a cylinder which holds the premixing nozzle therein.
- 29.** A gas turbine comprising:
- a compressor which compresses an air to generate a high-pressure gas;
- a combustor (10) according to claim 28, which is connected to the compressor so as to be supplied with the high-pressure gas from the compressor, and which heats the high-pressure gas to generate a high-temperature and high-pressure gas; and
- a turbine which is connected to the combustor (10) so as to be supplied with the high-temperature and high-pressure gas from the combustor, and which rotates an out shaft by expanding the high-temperature and high-pressure gas to generate a shaft output.
- 30.** A jet engine comprising:
- a compressor which compresses an air to generate a high-pressure gas;
- the combustor (10) according to claim 28, which is connected to the compressor so as to be supplied with the high-pressure gas from the compressor, and which heats the high-pressure gas to generate a high-temperature and high-pressure gas; and
- a turbine which is connected to the combustor

(10) so as to be supplied with the high-temperature and high-pressure gas from the combustor.

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FIG. 1A

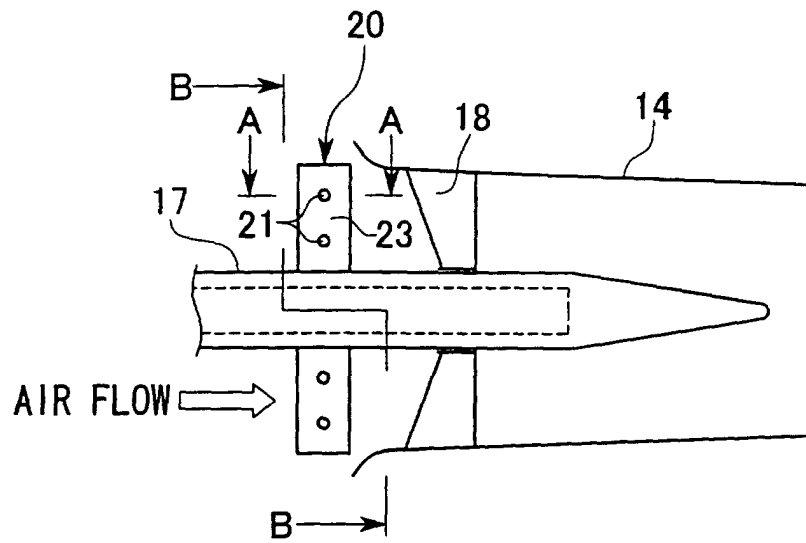


FIG. 1B

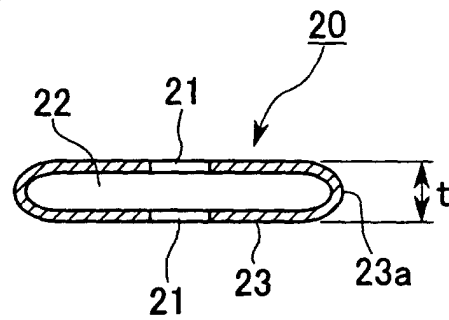


FIG. 1C

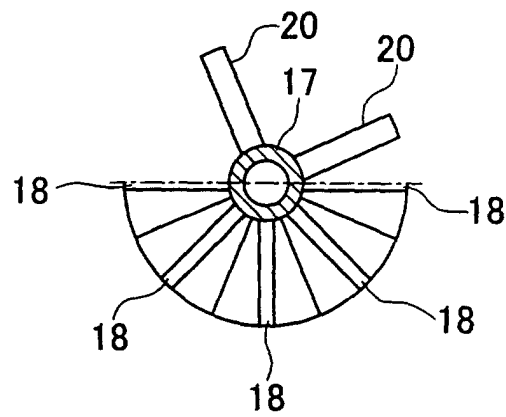


FIG. 2

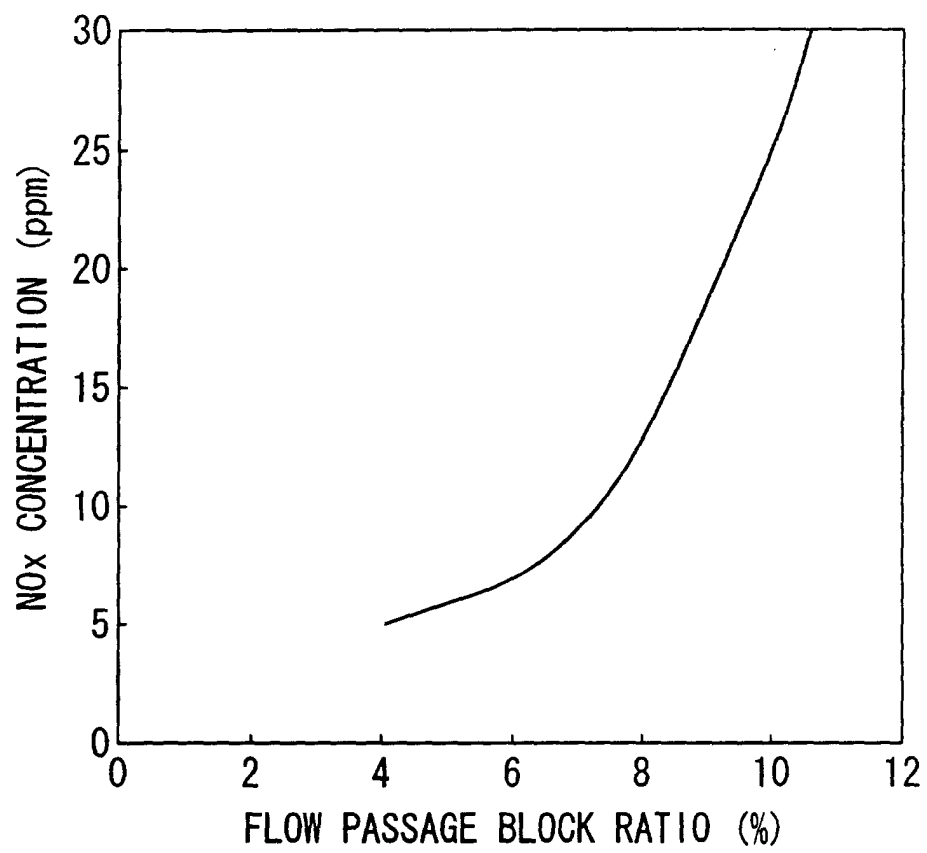


FIG. 3A

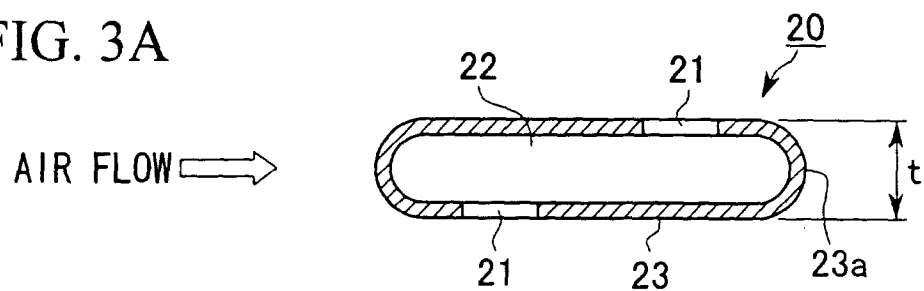


FIG. 3B

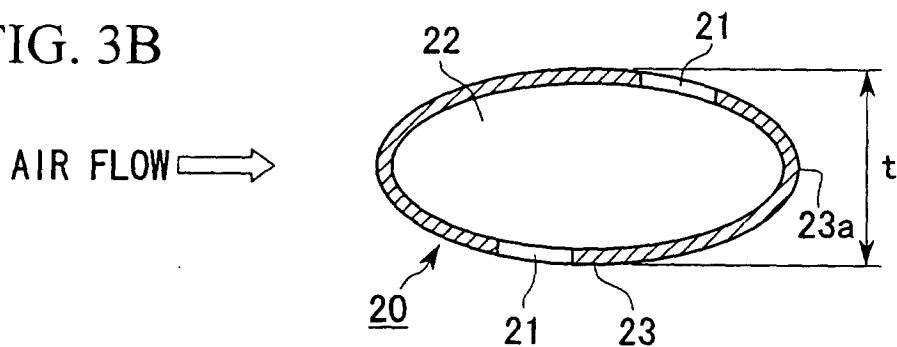


FIG. 3C

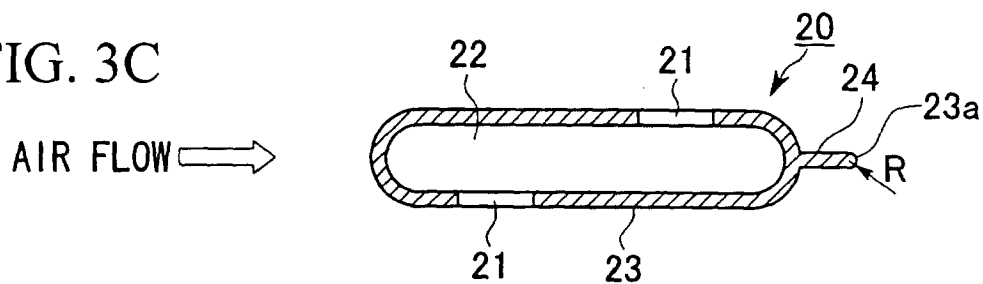


FIG. 3D

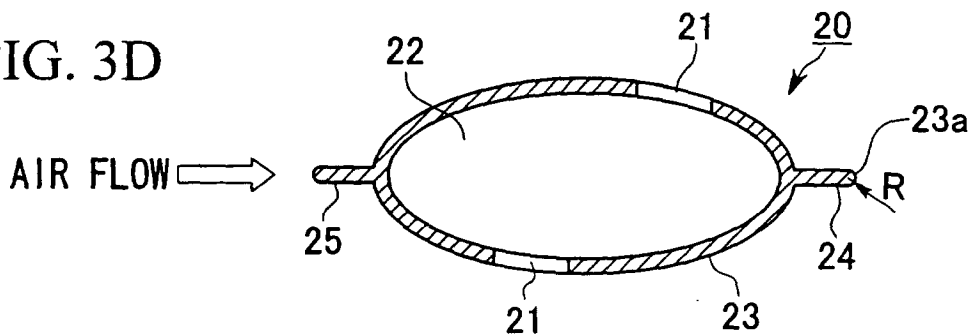


FIG. 3E

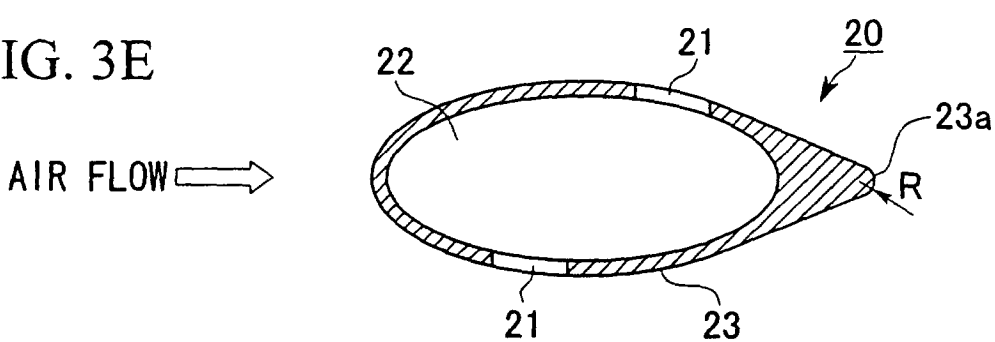


FIG. 4A

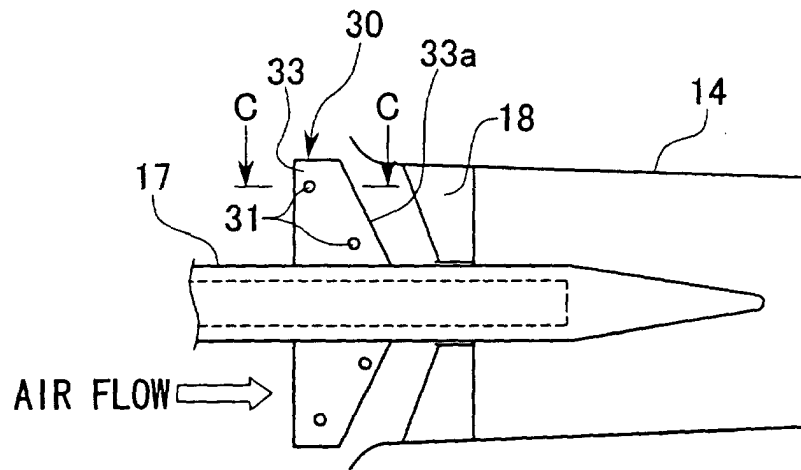


FIG. 4B

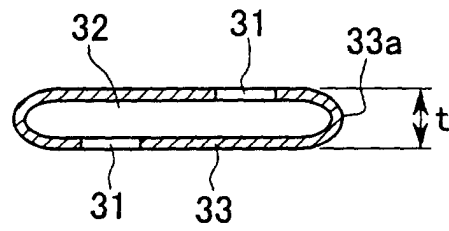


FIG. 5A

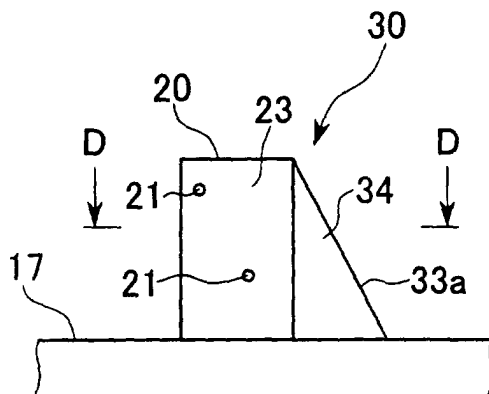


FIG. 5B

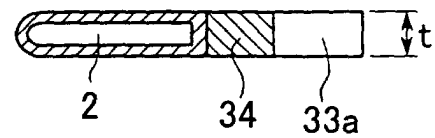


FIG. 6

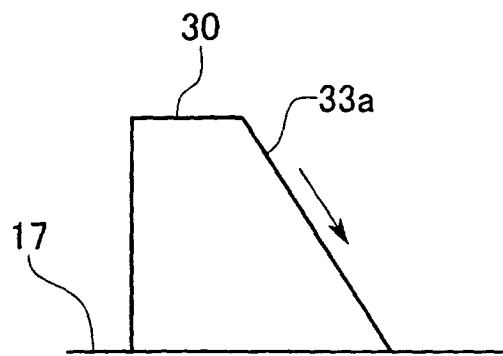


FIG. 7A

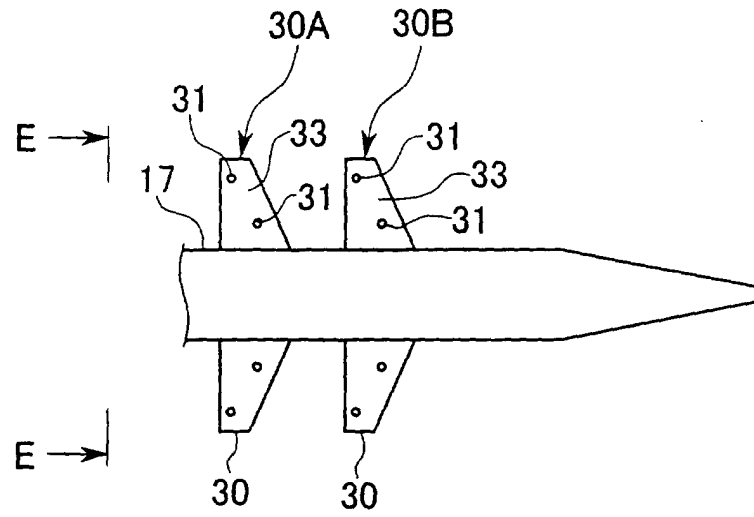


FIG. 7B

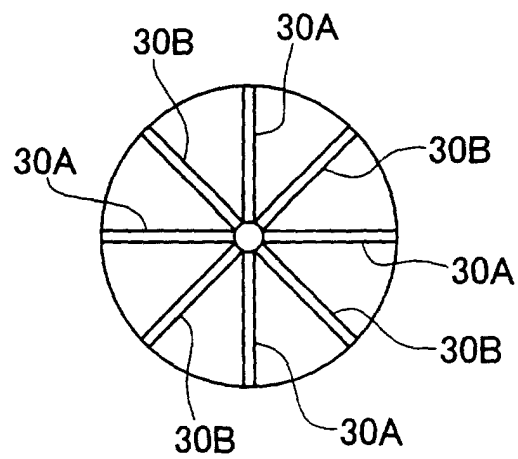


FIG. 8A

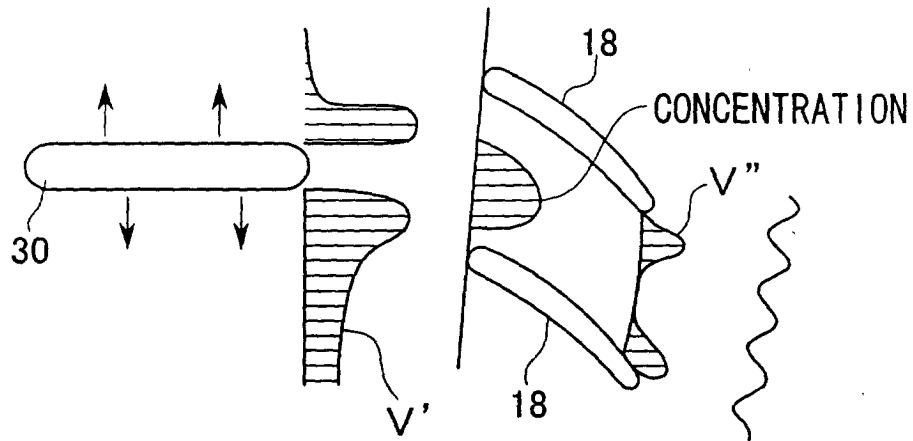


FIG. 8B

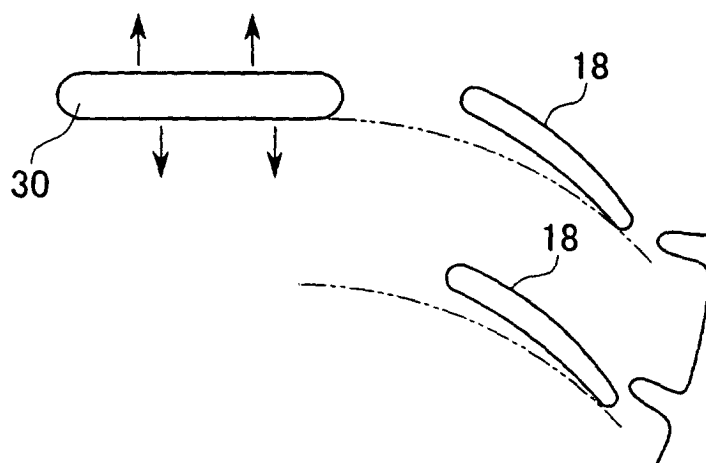


FIG. 9

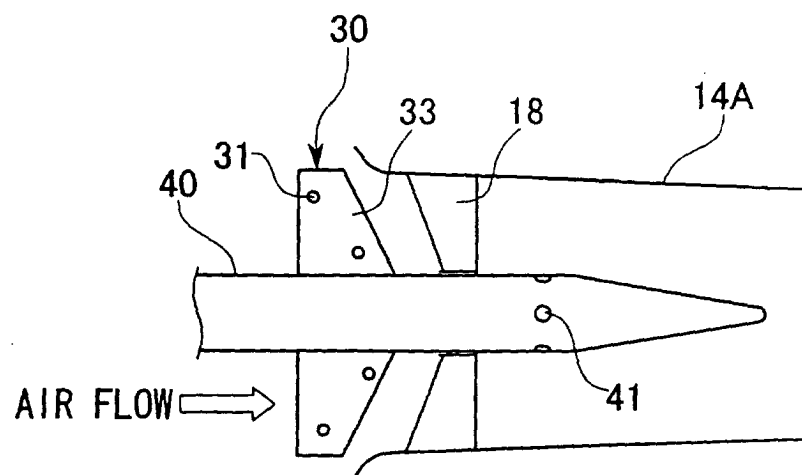


FIG. 10A

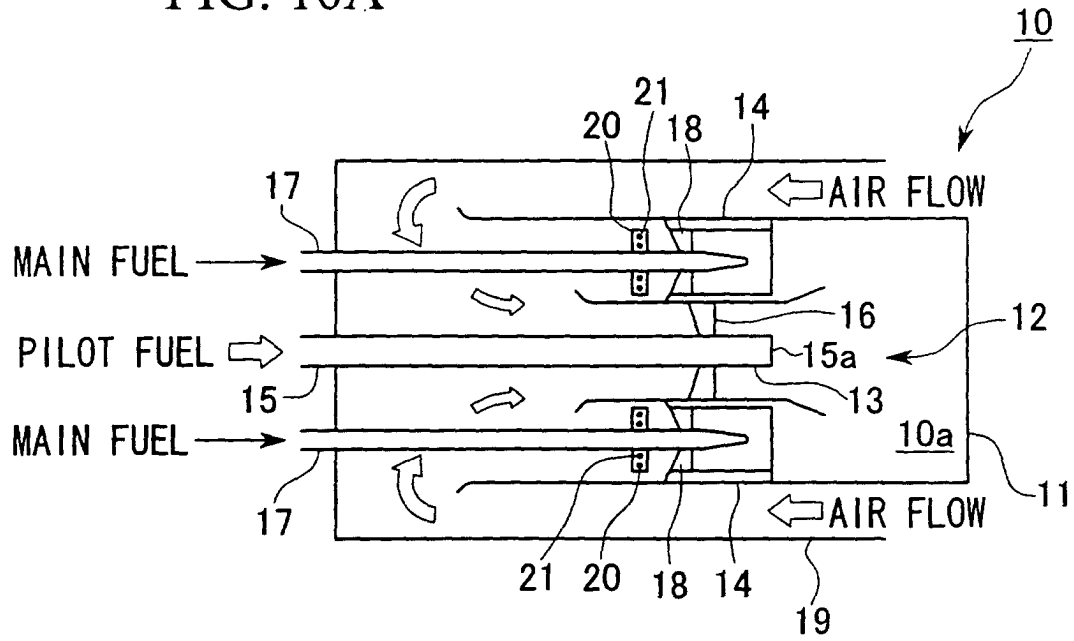


FIG. 10B

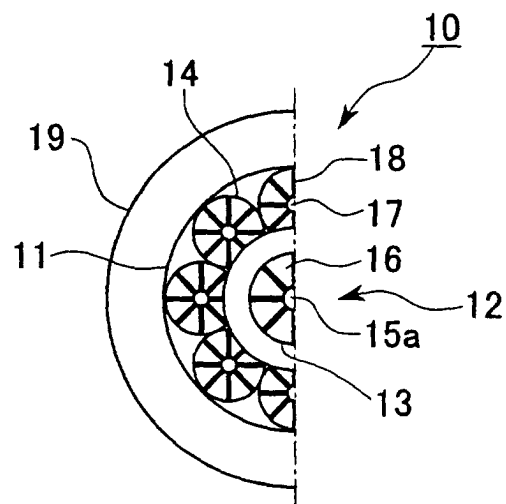
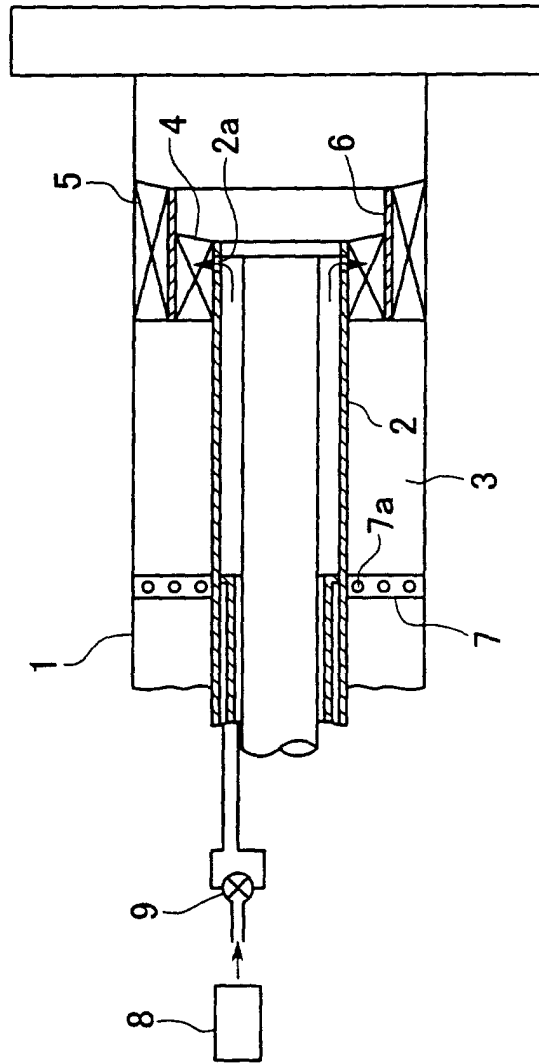


FIG. 11





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 40 1156

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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 17 October 2001	Examiner Mougey, M
CATEGORY OF CITED DOCUMENTS X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document		T: theory or principle underlying the invention E: earlier patent document, but published on, or after the filing date D: document cited in the application L: document cited for other reasons &: member of the same patent family, corresponding document	

EPC FORM 1503 03 82 (P04C01)



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
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			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 17 October 2001	Examiner Mougey, M
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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