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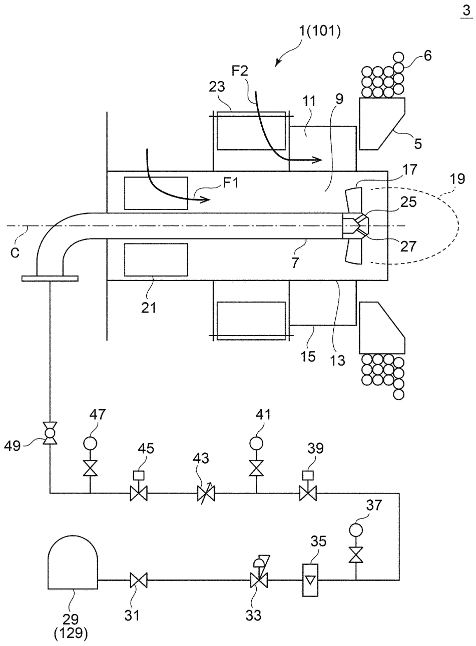
(54) GAS BURNER

(57) Provided is a gas burner comprising a nozzle through which a fuel gas flows, and a primary air supply unit for supplying, from the vicinity of the nozzle, primary air for which the ratio of air to the fuel gas is less than 1, the nozzle including at least one main hole configured so as to eject the fuel gas at an ejection angle of 25-45 degrees (inclusive) relative to the central axis of the gas burner, and at least one sub hole configured so as to eject the fuel gas at an ejection angle of 35-55 degrees (inclusive) relative to the central axis of the gas burner, said ejection angle being greater than the ejection angle of the main hole, and the gas pressure of the fuel gas flowing within the nozzle being 300 kPa or greater.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a gas burner such as a gas-fired boiler.

[0002] This application claims the priority of Japanese Patent Application No. 2021-106750 filed on June 28, 2021, the content of which is incorporated herein by reference.

BACKGROUND

[0003] Conventionally, a gas burner has been developed which suppresses combustion oscillation as well as suppresses generation of NOx (nitrogen oxide). For example, Patent Document 1 discloses a gas burner provided with, in a tip portion of a gas nozzle, a main hole for injecting a gas at an injection angle of 35° to 45° with respect to a central axis of the gas burner and a sub hole for injecting the gas at an injection angle of 45° to 55° with respect to the central axis of the gas burner.

Citation List

Patent Literature

[0004] Patent Document 1: JP4600850B

SUMMARY

Technical Problem

[0005] By applying the technique described in Patent Document 1, it is possible to suppress combustion oscillation, as well as it is possible to suppress the generation of NOx to some extent. However, while Patent Document 1 shows an example of 13A city gas (a gas containing methane as a principal component, and also containing ethane, propane, and butane as other components) as the type of gas fuel, Patent Document 1 does not indicate a gas fuel pressure.

[0006] Due to combustion oscillation or the like, it has been considered difficult to increase a pressure of gas fuel; for example, a boiler burner fueled by city gas or LPG (liquefied petroleum gas) is applied with a pressure at a maximum of about 130 KPa, and even when hydrogen is used as fuel, a maximum pressure is about 80 KPa.

[0007] On the other hand, it is desirable to be able to suppress the generation of NOx as much as possible, and improvements in suppressing combustion oscillation as well suppressing the generation of NOx are desired.

[0008] The present disclosure has been made in view of the above-described problems, and the object of the present disclosure is to provide a gas burner capable of suppressing combustion oscillation as well as suppressing the generation of NOx by increasing a pressure of gas fuel and setting an ejection angle of the gas fuel in a predetermined range.

Solution to Problem

[0009] In order to achieve the above object, a gas burner according to the present disclosure is a gas burner including: a nozzle where gas fuel flows; and a primary air supply part for supplying, from around the nozzle, primary air whose air ratio to the gas fuel is less than 1. The nozzle includes: at least one main hole configured to eject the gas fuel at an ejection angle of not less than 25 degrees and not greater than 45 degrees with respect to a central axis of the gas burner; and at least one sub hole configured to eject the gas fuel at an ejection angle of not less than 35 degrees and not greater than 55 degrees with respect to the central axis of the gas burner, the ejection angle of the sub hole being greater than the ejection angle of the main hole. The gas fuel flowing in the nozzle has a gas pressure of not less than 300 kPa.

Advantageous Effects

[0010] According to a gas burner of the present disclosure, combustion oscillation can be suppressed as well as generation of NOx can be suppressed by increasing a pressure of gas fuel and further setting ejection angles of the gas fuel from a main hole and a sub hole in predetermined ranges.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

FIG. 1 is a schematic side cross-sectional view showing a partial cross section of a gas burner according to one embodiment of the present disclosure, and is a schematic configuration view of a gas fuel supply system to the gas burner.
FIG. 2 is a side cross-sectional view of a gas nozzle (a cross-sectional view taken along line A-A in FIG. 3).
FIG. 3 is a front view of a tip portion of the gas nozzle as viewed from inside a furnace.
FIG. 4 is a graph of a test result showing a relationship between NOx and a hydrogen gas burner inlet pressure.
FIG. 5 is a schematic configuration view of a gas fuel supply system to a hydrogen gas burner when by-product hydrogen is applied.

DETAILED DESCRIPTION

[0012] Embodiments of the present disclosure will now be described in detail with reference to the accompanying drawings. It is intended, however, that unless particularly identified, dimensions, materials, shapes, relative positions and the like of components described or shown in the drawings as the embodiments shall be interpreted as illustrative only and not intended to limit the scope of the present disclosure.

<One embodiment>

[0013] FIG. 1 is a schematic side cross-sectional view showing a partial cross section of a gas burner 1 according to one embodiment of the present disclosure. The gas burner 1 is disposed in a burner throat part 5 on a side wall of a furnace 3. The gas burner 1 has a triple structure of a gas nozzle 7 disposed in a central axis C portion of the gas burner 1, a primary air flow passage (primary air supply part) 9 for introducing combustion air to an outer peripheral portion of the gas nozzle 7, and a secondary air flow passage 11 disposed in an outer peripheral portion of the primary air flow passage 9.
[0014] The gas nozzle 7 and the primary air flow passage 9 are disposed inside a cylindrical primary sleeve 13, and the secondary air flow passage 11 is formed inside a cylindrical secondary sleeve 15 disposed on an outer peripheral side of the primary sleeve 13.
[0015] The gas fuel is structured to be ejected into the furnace 3 from a main hole 25 and a sub hole 27 formed in the tip portion of the gas nozzle 7. A tertiary air flow passage (not shown) may be disposed in an outer peripheral portion of the secondary air flow passage 11. An opening part 4, which is opened in a furnace wall 1 in order to eject pulverized coal from a burner 3 toward a hot furnace 2 and is formed in a throat shape by a refractory material 20, is provided with an ejection port 23 for ejecting a cooling body such as air toward a surface of the refractory material 20.
[0016] Although primary air F1, which is central air flowing in from an opening part 21 forming an inlet and flowing through the primary air flow passage 9, is a straight flow, a swirling force is given to part of the primary air F1 by a swirler (flame holder) 17 disposed in an outlet section of the gas nozzle 7, that is, an outlet section of the primary air flow passage 9, a stagnant region 19 is formed in a region in the furnace 3 on a wake side of the swirler 17, and the gas fuel is taken into the stagnant region 19, making it possible to stably holding flame.
[0017] Further, an air register 23 is installed in an inlet section of the secondary air flow passage 11, and an air register type swirling device gives a swirling force to secondary air F2 flowing into the secondary air flow passage 11.
[0018] Further, in an outer peripheral portion of the burner throat part 5, which is an opening portion for the gas burner 1 formed in the side wall of the furnace 3, a water tube 6 is installed so as to surround the opening portion in order to cool the periphery of the opening portion.
[0019] The air ratio of the primary air F1 to the gas fuel ejected from the gas nozzle 7 is lower than the air ratio of the secondary air F2 to the gas fuel ejected from the gas nozzle 7, and further, the primary air F 1 supplied from the primary air flow passage 9 is set such that the air ratio to the ejected gas fuel is less than 1. The air ratio is the ratio of the amount of air when the amount of air required to completely burn the gas fuel is set to 1.
[0020] As shown in FIG. 2, 3, four main holes 25 and four sub holes 27 are disposed in the tip portion of the gas nozzle 7. It is configured such that the gas fuel flowing through all the main holes is 80% to 90% of the total gas fuel flow and the gas fuel flowing through all the sub holes is 20% to 10% of the total gas fuel flow. That is, the sub hole 27 is formed with a smaller hole diameter than the main hole 25 and a ratio A1:A2 is between 80:20 and 90: 10, where A1 is a total opening area of the plurality of main holes 25 and A2 is a total opening area of the plurality of sub holes 27.
[0021] Since it is configured such that, by setting the amount of the fuel ejected from the sub holes 27 less than the amount of the fuel ejected from the main holes 25, the gas fuel flowing through all the sub holes flows 20% to 10% of the total gas fuel flow, the fuel ejected from the sub holes 27 is easily taken into the stagnant region 19 formed on the

wake side of the swirler 17 for giving the swirling force to part of the primary air, thereby stably holding flame and making it possible to suppresses combustion oscillation.

[0022] Further, the swirler 17 for giving the swirling force to part of the primary air may be burned out if the fuel exceeding 20% is ejected from the sub holes 27. Therefore, it is preferably configured such that the gas fuel flowing through all the sub holes flows 20% to 10% of the total gas fuel flow.

[0023] Further, as shown in FIG. 2, 3, the plurality of (four) main holes 25 in the tip portion of the gas nozzle 7 are disposed around the central axis C of the gas nozzle 7 (which is also the central axis C of the gas burner 1) symmetrically with the central axis C therebetween, and are disposed so as to have an ejection angle of 50 degrees to 90 degrees with the central axis C of the gas nozzle 7 therebetween (an elevation angle of 25 degrees to 45 degrees with respect to the central axis C). Hereafter, the elevation angle of the main hole 25 with respect to the central axis C is referred to as a main hole ejection angle $\theta1$.

[0024] Further, the plurality of (four) sub holes 27 are disposed around the central axis C of the gas nozzle 7 symmetrically with the central axis C therebetween, and are disposed so as to have an ejection angle of 70 degrees to 110 degrees with the central axis C of the gas nozzle 7 therebetween (an elevation angle of 35 degrees to 55 degrees with respect to the central axis C). The ejection angle of the sub hole 27 is configured to eject the gas fuel at an ejection angle greater than the ejection angle of the main hole 25. Hereafter, the elevation angle of the sub hole 27 with respect to the central axis C is referred to as a sub hole ejection angle $\theta2$. The sub hole ejection angle $\theta2$ is configured to eject the gas fuel at an ejection angle greater than the main hole ejection angle.

[0025] The four main holes 25 and the four sub holes 27 are alternately and evenly disposed around the central axis C. That is, the main holes 25 and the sub holes 27 are disposed around the central axis C with an equal pitch angle α of 45 degrees. Since the plurality of main holes 25 are thus formed in the tip portion of the gas nozzle 7 so as to be disposed around the central axis C symmetrically with each other with the central axis C therebetween, the gas fuel ejected from the main holes 25 is evenly ejected without any bias with respect to the center of the gas burner 1.

[0026] Further, since the plurality of sub holes 27 are also formed in the tip portion of the gas nozzle 7 so as to be disposed around the central axis C symmetrically with each other with the central axis C therebetween, the gas fuel ejected from the sub holes 27 is evenly ejected without any bias with respect to the center of the gas burner 1.

[0027] In the front view shown in FIG. 3, a center position 25a of the opening of the main hole 25 and a center position 27a of the opening of the sub hole 27 are disposed such that a distance from the central axis C of the gas nozzle 7 is the same. In addition, the main hole 25 and the sub hole 27 have circular cross-sectional shapes.

[0028] Next, a system configuration for supplying gas fuel to the gas burner 1 will be described with reference to FIG. 1. An inlet valve 31 is provided, at an outlet of a gas tank 29 where gas fuel is stored, to control supply and shutoff of the gas fuel from the gas tank 29, and a pressure reducing valve 33 is provided, on an outlet side of the inlet valve 31, to reduce the pressure to a predetermined pressure.

[0029] Downstream of the pressure reducing valve 33, a flow rate meter 35, a thermometer 37, a shutoff valve 39, a pressure gauge 41, a flow control valve 43, a shutoff valve 45, a burner inlet pressure gauge 47, and a burner inlet valve 49 are disposed in order as shown in FIG. 1. Gas fuel is supplied to the gas nozzle 7 of the gas burner 1 by opening the burner inlet valve 49.

[0030] Therefore, the pressure of the gas fuel ejected from the main hole 25 and the sub hole 27 is a gas pressure of the gas fuel flowing in the gas nozzle 7 and is a pressure at the inlet of the gas burner 1, and is measured by the burner inlet pressure gauge 47. High-pressure gas fuel exceeding 300 kPa is pressurized and stored in the gas tank 29, and is supplied to the gas burner 1 after being depressurized, by the pressure reducing valve 33 etc., to a target gas pressure of not less than 300 kPa to be used.

[0031] According to one embodiment configured as described above, combustion oscillation can be suppressed as well as generation of NOx can be suppressed by increasing the gas pressure of the gas fuel to not less than 300 kPa and further setting the ejection angles of the gas fuel from the main hole 25 and the sub hole 27 in the predetermined ranges.

[0032] That is, if the air ratio is lowered, the temperature in the region where the fuel burns is lowered and generation of NOx is suppressed. Thereby, since the gas pressure of the gas fuel flowing in the gas nozzle 7 is set at not less than 300 kPa, mixing of the gas fuel and primary air with the air ratio of less than 1 is promoted, and the proportion of the gas fuel burning in the low-temperature region relatively increases. Whereby, it is possible to suppress generation of NOx.

[0033] Further, according to one embodiment, the gas burner 1 (gas nozzle 7) has the main hole 25 with the ejection angle of not less than 25 degrees and not greater than 45 degrees with respect to the central axis C of the gas burner 1 and the sub hole 27 with the ejection angle of not less than 35 degrees and not greater than 55 degrees with respect to the central axis C of the gas burner 1.

[0034] Slow combustion due to long flame of flame can be promoted by setting the main hole ejection angle $\theta1$ less than 45 degrees. If the main hole ejection angle $\theta1$ exceeds 45 degrees, the potential for combustion oscillation due to pressure fluctuations in the furnace 3 increases. If the main hole ejection angle $\theta1$ is less than 25 degrees, the long flame becomes excessive and affects heat absorption characteristics of the boiler. Therefore, since both stabilization and long flame of flame can be achieved by setting the main hole ejection angle θ1 to not less than 25 degrees and not greater than 45 degrees, it is possible to suppress combustion oscillation as well as it is possible to achieve the reduction in NOx by decreasing the flame temperature with the slow combustion due to the long flame.

[0035] As to the sub hole 27, the generation amount of NOx can be reduced by setting the sub hole ejection angle θ2 to less than 55 degrees. If the sub hole ejection angle θ2 exceeds 55 degrees, flame retention near the swirler 17 becomes too strong, increasing the burnout potential of the swirler 17 as well as causing concern about the increase in NOx. If the sub hole ejection angle θ2 is less than 35 degrees, the flame retention effect becomes weak and the oscillation potential increases. Therefore, combustion oscillation can be suppressed as well as the generation amount of NOx can be reduced by setting the sub hole ejection angle θ2 to not less than 35 degrees and not greater than 55 degrees.

[0036] Further, gas fuel is a compressible fluid, and has the property of expanding in the axial direction and the radial direction at once in the outlet section of the gas nozzle 7 as the gas fuel is increased in pressure. Therefore, even if the ejection angle is narrowed as the influence of the pressure, the narrowed angle is effective in ensuring flame retention by the sub hole 27 and avoiding the adverse effect on long flame by the main hole 25. Therefore, combustion oscillation can be suppressed as well as the generation amount of NOx can be reduced, even if the ejection angle is narrowed by reducing the elevation lower limit angle of the ejection angle disclosed in the conventional art (Patent Document 1).

<Another embodiment>

[0037] Next, another embodiment will be described. In another embodiment, it is configured such that the gas fuel is gas fuel containing hydrogen, the main hole ejection angle θ1 of the main hole 25 is not less than 25 degrees and not greater than 35 degrees, and the sub hole ejection angle θ2 of the sub hole 27 is not less than 35 degrees and not greater than 45 degrees.

[0038] The "gas fuel containing hydrogen" includes gas fuel containing hydrogen and other fuel (mixed combustion) and gas fuel containing only hydrogen (single combustion), and even the gas fuel containing hydrogen and other fuel can further be classified into fuel containing hydrogen as a principal component (the volume fraction of hydrogen is at least 50%) and fuel containing other fuel as a principal component (the volume fraction of hydrogen is less than 50%). The "gas fuel containing hydrogen" includes all of these cases.

[0039] In the configuration of the gas fuel supply system shown in FIG. 1, the gas tank 29 is a hydrogen gas tank 129 in which gas fuel containing hydrogen is stored, and the gas burner 1 is a hydrogen gas burner 101 for ejecting and burning gas fuel containing hydrogen. The other configurations of the gas fuel supply system are the same as in one embodiment shown in FIG. 1. Further, the structure of the hydrogen gas burner 101 is the same as that shown in FIGs. 1 to 3.

[0040] Gas fuel containing hydrogen at a high pressure exceeding 300 kPa (for example, 15 MPa) is pressurized and stored in the hydrogen gas tank 129, and is supplied to the hydrogen gas burner 101 after being depressurized, by the pressure reducing valve 33 etc., to the target gas pressure of not less than 300 kPa to be used.

[0041] Further, in a case where by-product hydrogen 51 produced in a factory is applied, since a supply pressure is as low as 3 to 50 KPa, as shown in FIG. 5, a booster 53 is applied in order to increase the pressure to the target gas pressure of not less than 300 kPa to be used and the by-product hydrogen 51 is supplied to the hydrogen gas burner 101.

[0042] FIG. 4 shows a relationship graph of a test result showing a relationship between NOx and an inlet pressure of the hydrogen gas burner 101 for gas fuel containing hydrogen (an ejection pressure from the main hole 25 and the sub hole 27). Test conditions are as shown in Table 1.

[Table 1]

Test condition	
Fuel type	Hydrogen single combustion
Fuel amount	95m3N/h
Total air ratio	1.1
Air ratio of primary air/secondary air	30/70

[0043] Further, the test checked the inlet pressure of the hydrogen gas burner 101 for four conditions of 80 KPa (comparison base), 300 KPa, 500 KPa, and 900 KPa. The change in ejection pressure was tested by changing the hole diameters of the main hole 25 and the sub hole 27 formed in the tip portion of the gas nozzle 7 while keeping the fuel amount constant, without changing the structure of the hydrogen gas burner 101. For example, the hole diameters were changed as shown in Table 2. Further, the ejection angles of the main hole 25 and the sub hole 27 during the combustion test are 40° for the main hole ejection angle θ1 and 45° for the sub hole ejection angle θ2.

[Table 2]

Ejection pressure	Main hole	Sub hole
900 KPa	φ1.1	φ0.5
500 KPa	φ1.4	φ0.7
300 KPa	φ1.7	φ0.9
80 KPa	φ2.5	φ1.3

[0044] In general, a boiler burner fueled by city gas, LPG, or the like is applied at a maximum of about 130 KPa, and even when hydrogen is used as fuel, a maximum pressure is about 80 KPa, and thus 80 KPa was used as the base for comparison. As shown in the graph of the test result in FIG. 4, it was confirmed that NOx was reduced at 300 KPa, 500 KPa, and 900 KPa. 900 KPa showed a NOx reduction effect of about 30%. Therefore, not less than 300 KPa at which the NOx reduction effect was seen was set as a setting pressure for the increased pressure. It is more desirable to set the pressure at not less than 500 KPa.

[0045] The trend of the test result showing the relationship between NOx and the inlet pressure of the hydrogen gas burner 101 (the ejection pressure from the main hole 25 and the sub hole 27) is considered to be equal in the gas fuel such as city gas or LPG other than the gas fuel containing hydrogen. In the combustion test using LPG, relative to base NOx at the ejection pressure of 70 KPa, the NOx reductions of about 20% at 300 KPa and about 25% at 500 KPa were confirmed. Therefore, not less than 300 KPa at which the NOx reduction effect was seen was set as the setting pressure for the increased pressure. It is more desirable to set the pressure at not less than 500 KPa.

[0046] In the case of the gas fuel containing hydrogen, if the main hole ejection angle $\theta 1$ exceeds 35 degrees, the potential for combustion oscillation due to the pressure fluctuations in the furnace 3 increases. Further, if the main hole ejection angle $\theta 1$ is less than 25 degrees, the long flame becomes excessive and affects the heat absorption characteristics of the boiler. Therefore, since both stabilization and long flame of flame can be achieved by setting the main hole ejection angle $\theta 1$ between 25 degrees and 35 degrees, it is possible to suppress combustion oscillation as well as it is possible to achieve the reduction in NOx by decreasing the flame temperature with the slow combustion due to the long flame.

[0047] Since hydrogen has relatively short flame due to its high combustion speed and superior combustibility compared to city gas or LPG, there is no problem with the influence on combustion oscillation even if the main hole ejection angle $\theta 1$ is narrowed in the range of not less than 25 degrees and not greater than 35 degrees compared to one embodiment. That is, since combustion oscillation is less likely to occur in the gas fuel containing hydrogen even if said gas fuel is increased in pressure, the flame temperature is reduced by slow combustion due to the long flame caused by the increase in pressure and the reduction in NOx can more effectively be achieved even if the ejection angle from the main hole 25 is narrowed.

[0048] Further, as to the sub hole 27, if the sub hole ejection angle $\theta 2$ is less than 35 degrees, the flame retention effect becomes weak and the oscillation potential increases. In addition, if the sub hole ejection angle $\theta 2$ exceeds 45 degrees, the balance of flame retention near the burner is lost and the oscillation potential increases. Therefore, the appropriate range for the sub hole ejection angle $\theta 2$ is between 35 degrees and 45 degrees.

[0049] Since hydrogen has good flame retention due to its high combustion speed and superior combustibility compared to city gas or LPG, there is no problem with the influence on combustion oscillation even if the sub hole ejection angle $\theta 2$ is narrowed in the range of not less than 35 degrees and not greater than 45 degrees compared to one embodiment. That is, also in the sub hole 27, as in the case of the main hole 25, since combustion oscillation is less likely to occur in the gas fuel containing hydrogen even if said gas fuel is increased in pressure, the flame temperature is reduced by slow combustion due to the long flame caused by the increase in pressure and the reduction in NOx can more effectively be achieved even if the ejection angle from the sub hole 27 is narrowed.

[0050] According to the another embodiment described above, the combustion oscillation can be suppressed as well as the generation amount of NOx can further be reduced by increasing the ejection pressure of the gas fuel containing hydrogen to not less than 300 KPa, as well as by setting the ejection angle from the main hole 25 between 25 degrees and 35 degrees and by setting the ejection angle from the sub hole 27 to not less than 35 degrees to and not greater than 45 degrees.

[0051] As for the rest, without departing from the spirit of the present disclosure, it is possible to replace the constituent elements in the above-described embodiments with known constituent elements, respectively, as needed and further, the above-described embodiments may be combined as needed.

[0052] The contents described in the above embodiments would be understood as follows, for instance.

(1) A gas burner according to one aspect is a gas burner including: a nozzle (the gas nozzle 7 described in one embodiment) where gas fuel flows; and a primary air supply part (the primary air flow passage 9 described in one embodiment) for supplying, from around the nozzle, primary air whose air ratio to the gas fuel is less than 1. The nozzle includes: at least one main hole (the main hole 25 described in one embodiment) configured to eject the gas fuel at an ejection angle (the main hole ejection angle θ1 described in one embodiment) of not less than 25 degrees and not greater than 45 degrees with respect to a central axis (the central axis C described in one embodiment) of the gas burner; and at least one sub hole (the sub hole 27 described in one embodiment) configured to eject the gas fuel at an ejection angle (the sub hole ejection angle θ2 described in one embodiment) of not less than 35 degrees and not greater than 55 degrees with respect to the central axis of the gas burner, the ejection angle of the sub hole being greater than the ejection angle of the main hole. The gas fuel flowing in the nozzle has a gas pressure of not less than 300 kPa.

[0053] With the gas burner according to the present disclosure, since the gas pressure of the gas fuel is increased to not less than 300 kPa, and further, the nozzle includes the main hole with the ejection angle of not less than 25 degrees and not greater than 45 degrees with respect to the central axis of the gas burner and the sub hole with the ejection angle of not less than 35 degrees and not greater than 55 degrees with respect to the central axis of the gas burner, it is possible to suppress combustion oscillation, as well as it is possible to suppress generation of NOx.

[0054] If the air ratio is lowered, the temperature in the region where the fuel burns is lowered and generation of NOx is suppressed. According to the configuration (1), since the gas pressure of the gas fuel flowing in the nozzle is set at not less than 300 kPa, mixing of the gas fuel and primary air with the air ratio of less than 1 is promoted, and the proportion of the gas fuel burning in the low-temperature region relatively increases. Whereby, it is possible to suppress generation of NOx.

[0055] Further, according to the configuration (1), the nozzle has the main hole with the ejection angle of not less than 25 degrees and not greater than 45 degrees with respect to the central axis of the gas burner and the sub hole with the ejection angle of not less than 35 degrees and not greater than 55 degrees with respect to the central axis of the gas burner. Slow combustion due to long flame of flame can be promoted by setting the ejection angle of the gas fuel from the main hole (elevation angle with respect to the central axis of the gas burner) to less than 45 degrees. If the ejection angle of the main hole exceeds 45 degrees, the potential for combustion oscillation due to pressure fluctuations in the furnace increases. If the ejection angle of the main hole is less than 25 degrees, the long flame becomes excessive and affects the heat absorption characteristics of the boiler. Therefore, since both stabilization and long flame of flame can be achieved by setting the ejection angle of the main hole to not less than 25 degrees and not greater than 45 degrees, it is possible to suppress combustion oscillation as well as it is possible to achieve the reduction in NOx by decreasing the flame temperature with the slow combustion due to the long flame.

[0056] As to the sub hole, the generation amount of NOx can be reduced by setting the ejection angle of the sub hole to less than 55 degrees. If the ejection angle of sub hole exceeds 55 degrees, the balance of flame retention near the burner is lost and the oscillation potential increases. If the ejection angle of sub hole is less than 35 degrees, the flame retention effect becomes weak and the oscillation potential increases. Therefore, combustion oscillation can be suppressed as well as the generation amount of NOx can be reduced by setting the ejection angle of the sub hole to not less than 35 degrees and not greater than 55 degrees.

[0057] (2) The gas burner according to another aspect is the gas burner as defined in (1), wherein the gas fuel contains hydrogen.

[0058] According to such configuration (2), since hydrogen has a high combustion speed and superior combustibility compared to 13A city gas (a gas containing methane as a principal component, and also containing ethane, propane, and butane as other components) shown as the gas fuel in the conventional art (Patent Document 1), flame retention is enhanced and the potential for combustion oscillation can be reduced compared to city gas or LPG (liquefied petroleum gas).

[0059] (3) The gas burner according to still another aspect is the gas burner as defined in (2), wherein the ejection angle of the main hole is not less than 25 degrees and not greater than 35 degrees, and the ejection angle of the sub hole is not less than 35 degrees and not greater than 45 degrees.

[0060] According to such configuration (3), since hydrogen has relatively short flame due to its high combustion speed and superior combustibility compared to city gas or LPG, the potential for combustion oscillation can be reduced compared to the case of city gas or LPG. Therefore, there is no problem with the influence on heat absorption characteristics of the boiler even if the ejection angle from the main hole of the configuration (1) is narrowed from the range of 25° to 45° to the range of 25° to 35°, and it is possible to suppress combustion oscillation as well as it is possible to achieve the reduction in NOx by decreasing the flame temperature with the slow combustion due to the long flame.

[0061] Further, as to the sub hole, since hydrogen has the high combustion speed and superior combustibility compared to city gas or LPG, the potential for combustion oscillation can be reduced compared to the case of the fuel such as city gas or LPG. Therefore, there is no problem with the influence on combustion oscillation even if the ejection angle from the sub hole of the configuration (1) is narrowed from the range of 35° to 55° to the range of 35° to 45°, and it is possible to suppress combustion oscillation as well as it is possible to achieve the reduction in NOx by decreasing the flame temperature with the slow combustion due to the long flame.

[0062] (4) The gas burner according to yet another aspect is the gas burner as defined in any of (1) to (3), wherein the at least one main hole includes a plurality of main holes formed in a tip portion of the nozzle such that the plurality of main holes are disposed around the central axis of the gas burner symmetrically with each other with the central axis of the gas burner therebetween.

[0063] According to such configuration (4), the gas fuel containing hydrogen ejected from the main holes can evenly be ejected without any bias with respect to the center of the gas burner, making it possible to address, without delay, slow combustion due to long flame.

[0064] (5) The gas burner according to yet another aspect is the gas burner as defined in any of (1) to (4), wherein the at least one sub hole includes a plurality of sub holes formed in a tip portion of the nozzle such that the plurality of sub holes are disposed around the central axis of the gas burner symmetrically with each other with the central axis of the gas burner therebetween.

[0065] According to such configuration (5), the gas fuel containing hydrogen ejected from the sub holes can evenly be ejected without any bias with respect to the center of the gas burner, making it possible to evenly form the flame retention region around the swirler (flame holder) and to reduce the potential for combustion oscillation.

[0066] (6) The gas burner according to yet another aspect is the gas burner as defined in any of (1) to (5), wherein a ratio A1 :A2 is between 80:20 and 90: 10, where A1 is a total opening area of a plurality of the main holes and A2 is a total opening area of a plurality of the sub holes.

[0067] According to such configuration (6), an appropriate amount of fuel for flame retention ejected from the sub hole is easily taken into the stagnant region having a low flow velocity suitable for flame retention and formed on the wake side of the swirler (flame holder) for applying the swirling force to part of the primary air, and the flame near the swirler is kept stable and combustion oscillation can be suppressed. In addition, if the fuel exceeding 20% is ejected from the sub hole, the swirler for applying the swirling force to part of the primary air has the risk of burnout, the configuration (6) can prevent such risk.

Reference Signs List

[0068]

1	Gas burner
3	Furnace
5	Burner throat part
6	Water tube
7	Gas nozzle (nozzle)
9	Primary air flow passage (primary air supply part)
11	Secondary air flow passage
13	Primary sleeve
15	Secondary sleeve
17	Swirler (flame holder)
19	Stagnant region
21	Opening part
23	Air register
25	Main hole
27	Sub hole
29	Gas tank
31	Inlet valve
33	Pressure reducing valve
35	Flow rate meter
37	Thermometer
39, 45	Shutoff valve
41	Pressure gauge
43	Flow control valve
47	Burner inlet pressure gauge
49	Burner inlet valve
51	By-product hydrogen
53	Booster

101	Hydrogen gas burner
129	Hydrogen gas tank
C	Central axis of gas burner and gas nozzle
F1	Primary air
F2	Secondary air
θ1	Main hole ejection angle
θ2	Sub hole ejection angle

Claims

1. A gas burner comprising:

a nozzle where gas fuel flows; and
a primary air supply part for supplying, from around the nozzle, primary air whose air ratio to the gas fuel is less than 1,
wherein the nozzle includes:

at least one main hole configured to eject the gas fuel at an ejection angle of not less than 25 degrees and not greater than 45 degrees with respect to a central axis of the gas burner; and
at least one sub hole configured to eject the gas fuel at an ejection angle of not less than 35 degrees and not greater than 55 degrees with respect to the central axis of the gas burner, the ejection angle of the sub hole being greater than the ejection angle of the main hole, and

wherein the gas fuel flowing in the nozzle has a gas pressure of not less than 300 kPa.

2. The gas burner according to claim 1,
wherein the gas fuel contains hydrogen.

3. The gas burner according to claim 2,
wherein the ejection angle of the main hole is not less than 25 degrees and not greater than 35 degrees, and the ejection angle of the sub hole is not less than 35 degrees and not greater than 45 degrees.

4. The gas burner according to claim 1,
wherein the at least one main hole includes a plurality of main holes formed in a tip portion of the nozzle such that the plurality of main holes are disposed around the central axis of the gas burner symmetrically with each other with the central axis of the gas burner therebetween.

5. The gas burner according to claim 1,
wherein the at least one sub hole includes a plurality of sub holes formed in a tip portion of the nozzle such that the plurality of sub holes are disposed around the central axis of the gas burner symmetrically with each other with the central axis of the gas burner therebetween.

6. The gas burner according to claim 1,
wherein a ratio A1:A2 is between 80:20 and 90: 10, where A1 is a total opening area of a plurality of the main holes and A2 is a total opening area of a plurality of the sub holes.

Amended claims under Art. 19.1 PCT

1. A gas burner disposed in a facility including a furnace, comprising:

a nozzle where gas fuel flows; and
a primary air supply part for supplying, from around the nozzle, primary air whose air ratio to the gas fuel is less than 1,
wherein the nozzle includes:

at least one main hole configured to eject the gas fuel at an ejection angle of not less than 25 degrees and

not greater than 45 degrees with respect to a central axis of the gas burner; and
at least one sub hole configured to eject the gas fuel at an ejection angle of not less than 35 degrees and not greater than 55 degrees with respect to the central axis of the gas burner, the ejection angle of the sub hole being greater than the ejection angle of the main hole, and

wherein the gas fuel flowing in the nozzle has a gas pressure of not less than 300 kPa.

2. The gas burner according to claim 1,
wherein the gas fuel contains hydrogen.

3. The gas burner according to claim 2,
wherein the ejection angle of the main hole is not less than 25 degrees and not greater than 35 degrees, and the ejection angle of the sub hole is not less than 35 degrees and not greater than 45 degrees.

4. The gas burner according to claim 1,
wherein the at least one main hole includes a plurality of main holes formed in a tip portion of the nozzle such that the plurality of main holes are disposed around the central axis of the gas burner symmetrically with each other with the central axis of the gas burner therebetween.

5. The gas burner according to claim 1,
wherein the at least one sub hole includes a plurality of sub holes formed in a tip portion of the nozzle such that the plurality of sub holes are disposed around the central axis of the gas burner symmetrically with each other with the central axis of the gas burner therebetween.

6. The gas burner according to claim 1,
wherein a ratio A1:A2 is between 80:20 and 90: 10, where A1 is a total opening area of a plurality of the main holes and A2 is a total opening area of a plurality of the sub holes.

7. A gas burner disposed in a facility including a furnace, comprising:

a nozzle where gas fuel containing hydrogen flows; and
a primary air supply part for supplying, from around the nozzle, primary air whose air ratio to the gas fuel is less than 1,
wherein the nozzle includes:

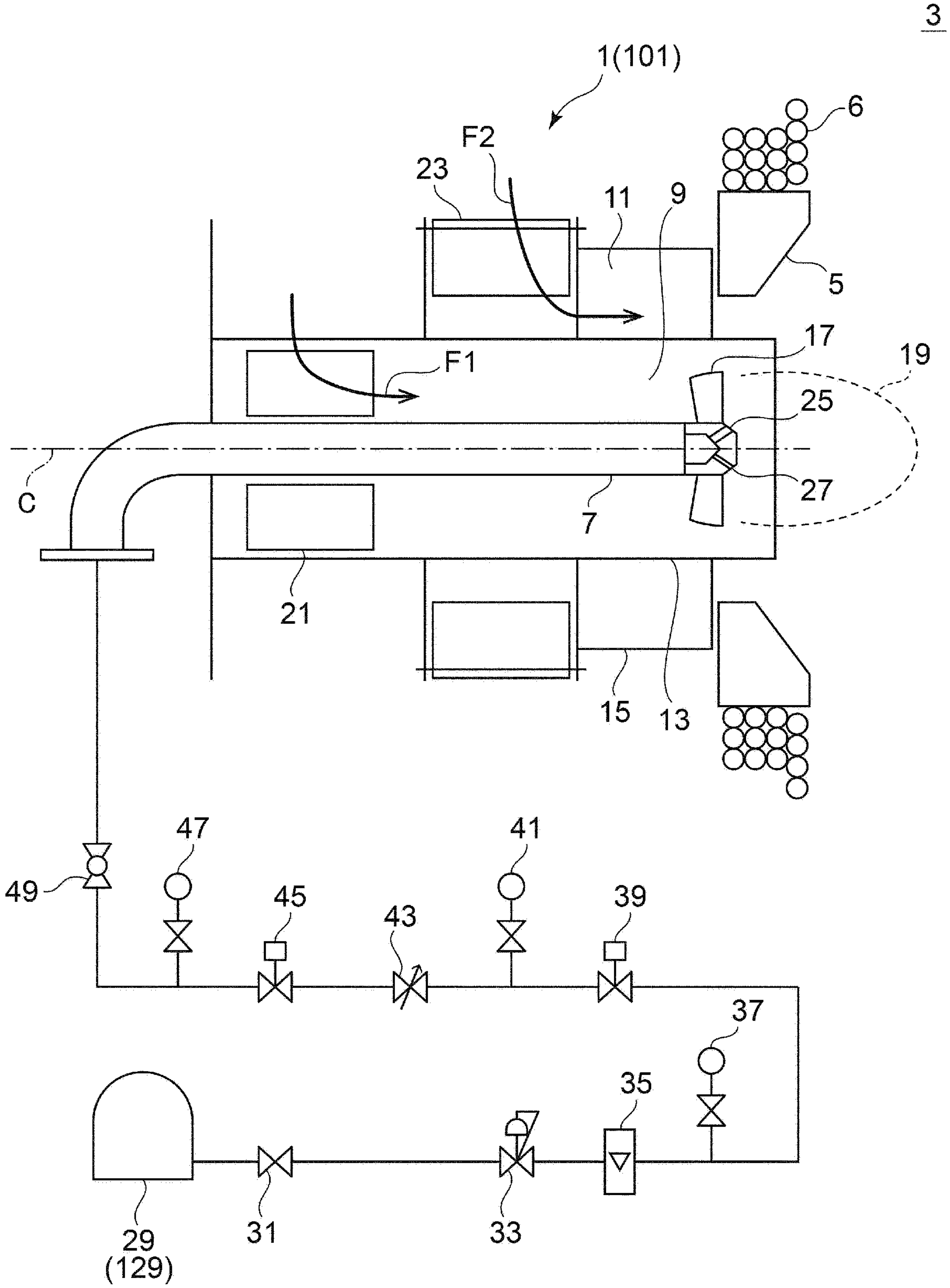
at least one main hole configured to eject the gas fuel at an ejection angle of not less than 25 degrees and not greater than 35 degrees (excluding 35 degrees) with respect to a central axis of the gas burner; and
at least one sub hole configured to eject the gas fuel at an ejection angle of not less than 35 degrees and not greater than 45 degrees (excluding 45 degrees) with respect to the central axis of the gas burner, the ejection angle of the sub hole being greater than the ejection angle of the main hole, and

wherein the gas fuel flowing in the nozzle has a gas pressure of not less than 300 kPa.

8. A facility comprising:

a furnace, and
the gas burner according to any one of claims 1 to 7.

FIG. 1


3
1(101)
6
F2
23
11
9
5
17
19
F1
25
C
27
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21
15
13
47
41
49
45
43
39
37
35
29
(129)
31
33

FIG. 2

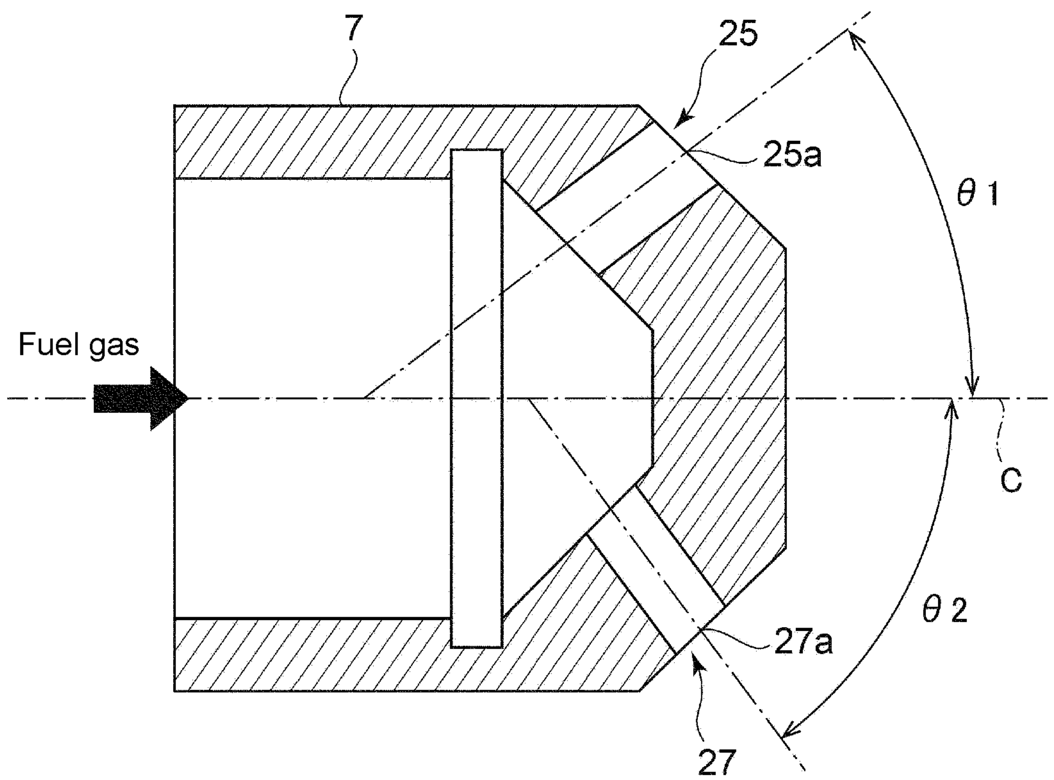


FIG. 3

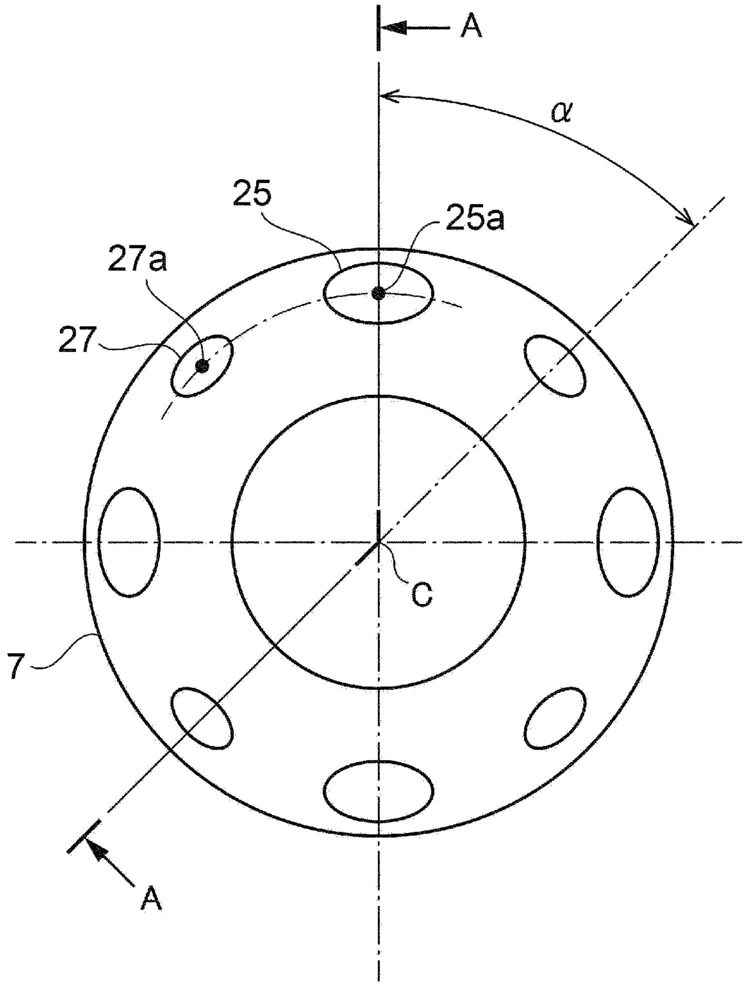


FIG. 4

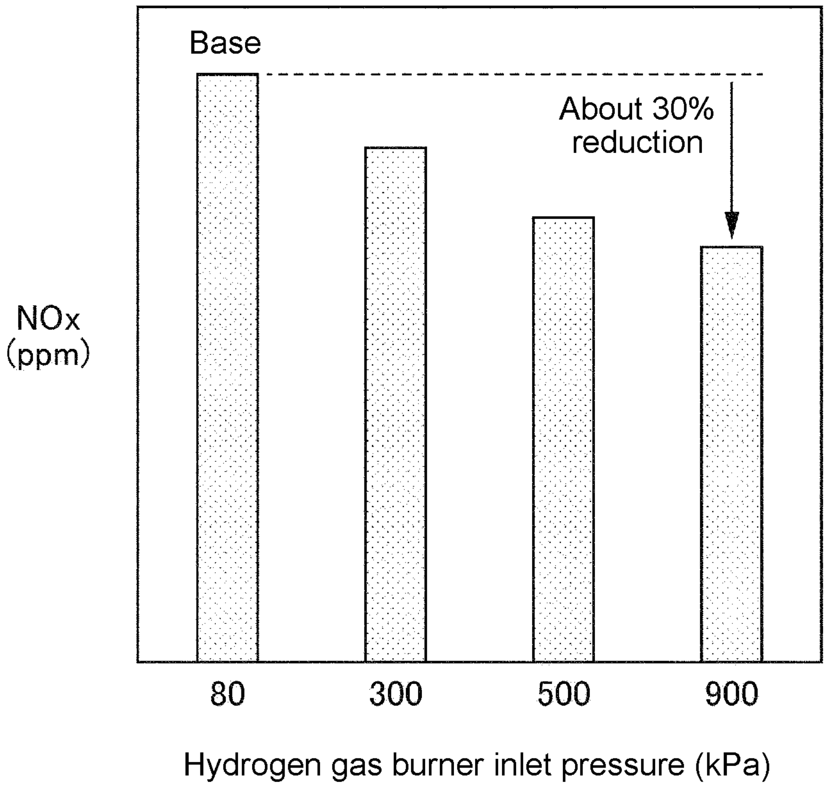
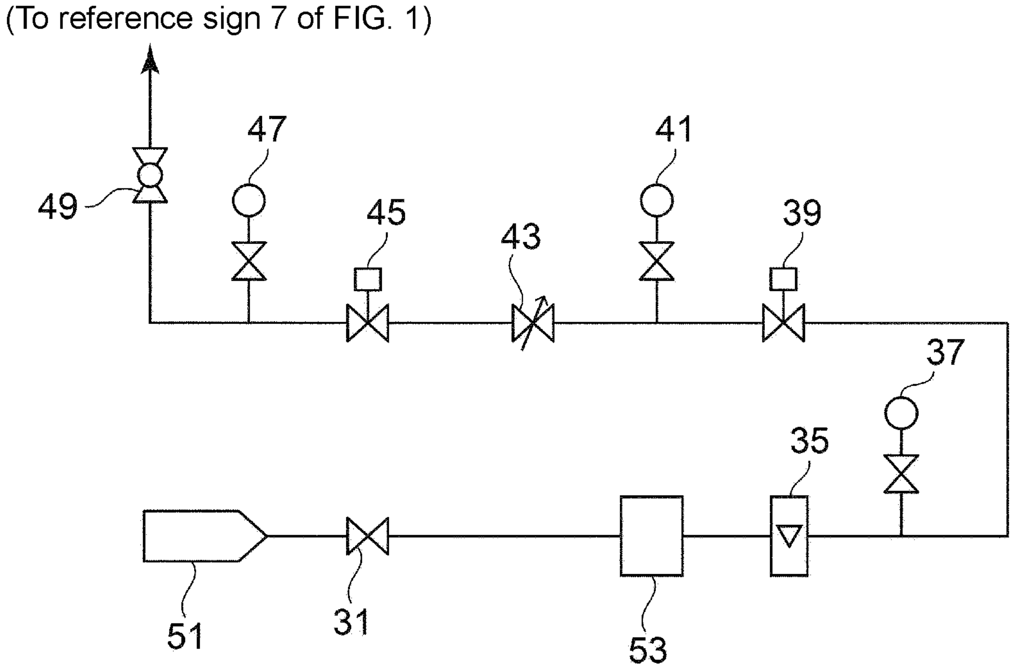

Base
About 30%
reduction
NOx
(ppm)
80
300
500
900
Hydrogen gas burner inlet pressure (kPa)

FIG. 5



INTERNATIONAL SEARCH REPORT

International application No. **PCT/JP2022/024271**

A. CLASSIFICATION OF SUBJECT MATTER

F23C 99/00(2006.01)i; ***F23D 14/22***(2006.01)i
FI: F23C99/00 330; F23D14/22 E

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F23C99/00; F23D14/22

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2008-111591 A (BAB-HITACHI INDUSTRIAL CO.) 15 May 2008 (2008-05-15) paragraphs [0001], [0009], [0017]-[0035], claims 1-2, fig. 1-8	1-6
Y	JP 2018-9676 A (KEIHIN CORP.) 18 January 2018 (2018-01-18) paragraph [0037]	1-6
Y	JP 2006-169357 A (NIHONKAI GAS CO., LTD.) 29 June 2006 (2006-06-29) paragraph [0025]	2-3
A	JP 8-178224 A (ISHIKAWAJIMA HARIMA HEAVY IND. CO., LTD.) 12 July 1996 (1996-07-12) entire text, all drawings	1-6
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 53122/1988 (Laid-open No. 157908/1989) (KUWABARA SEISAKUSHO KK) 31 October 1989 (1989-10-31), entire text, all drawings	1-6
A	JP 1-502212 A (INST. FRANCAIS DU PETROLE) 03 August 1989 (1989-08-03) entire text, all drawings	1-6

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 July 2022	**19 July 2022**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/024271

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 51-148828 A (MITSUI ENGINEERING & SHIPBUILDING CO., LTD.) 21 December 1976 (1976-12-21) entire text, all drawings	1-6
A	JP 2012-87984 A (OSAKA PREFECTURE UNIV.) 10 May 2012 (2012-05-10) entire text, all drawings	1-6

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/024271

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2008-111591 A	15 May 2008	(Family: none)	
JP 2018-9676 A	18 January 2018	(Family: none)	
JP 2006-169357 A	29 June 2006	(Family: none)	
JP 8-178224 A	12 July 1996	(Family: none)	
JP 1-157908 U1	31 October 1989	(Family: none)	
JP 1-502212 A	03 August 1989	US 5147199 A WO 1988/004391 A1 FR 2608257 A1	
JP 51-148828 A	21 December 1976	(Family: none)	
JP 2012-87984 A	10 May 2012	(Family: none)	

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2021106750 A **[0002]**
- JP 4600850 B **[0004]**