

DESCRIPTION

TITLE BURNER

5

TECHNICAL FIELD

[0001] The present disclosure relates to a burner.

BACKGROUND

10 **[0002]** A burner using a fuel gas and a combustion-supporting gas is known.
For example, see Patent Literature (PTL) 1.

CITATION LIST

Patent Literature

15 **[0003]** PTL 1: JP 4261753 B2

SUMMARY

(Technical Problem)

20 **[0004]** A burner that burns fuel with an oxidizer is generally used as a heat
source in industrial furnaces, such as metal heating furnaces, glass melting
furnaces, and aluminum melting furnaces. Various fossil fuels are used as the
fuel, including solid fuels such as pulverized coal, liquid fuels such as
kerosene or heavy oil, or gaseous fuels such as natural gas or LPG. In an
industrial furnace, an object to be heated is heated by radiant heat transfer
25 from a flame generated by burning fuel.

[0005] When fossil fuels are used, the combustion exhaust gas contains a
large amount of CO₂, and therefore, in recent years, the use of ammonia has
been proposed.

30 **[0006]** Ammonia has the characteristic of not producing CO₂ when burned,
but since it contains no carbon, the flame radiation intensity is reduced and
the flame tends to be unstable due to a low combustion rate.

[0007] It is therefore an aim of the present disclosure to provide a burner that
uses ammonia as fuel and can suppress the generation of NO_x while ensuring
radiation intensity and flame stability.

35 (Solution to Problem)

[0008] An aspect of the present disclosure is as follows.

[0009] [1]

A burner comprising:

a fuel gas supply pipe configured to supply a fuel gas containing ammonia and eject the fuel gas from a fuel gas ejection hole at a tip thereof;

5 a first combustion-supporting gas supply pipe provided radially outward from the fuel gas supply pipe so as to surround the fuel gas supply pipe and configured to supply a first combustion-supporting gas and eject the first combustion-supporting gas from a first combustion-supporting gas ejection hole at a tip thereof; and

10 a second combustion-supporting gas supplier configured to supply a second combustion-supporting gas and eject the second combustion-supporting gas from a second combustion-supporting gas ejection hole so that the second combustion-supporting gas joins a burner flame downstream from the first combustion-supporting gas ejection hole, wherein

15 an oxygen concentration of a combustion-supporting gas that is a combination of the first combustion-supporting gas and the second combustion-supporting gas is 30 % or more,

an oxygen concentration of the second combustion-supporting gas is 90 % or more, and

20 $0.38 \leq (V_1 + V_2)/V_3 \leq 1.1$, where V_1 is a volumetric flow rate of oxygen at the first combustion-supporting gas ejection hole, V_2 is a volumetric flow rate of oxygen at the second combustion-supporting gas ejection hole, and V_3 is a volumetric flow rate of ammonia at the fuel gas ejection hole.

25 **[0010] [2]**

The burner according to [1], wherein $0.1 \leq q_1/q_2 \leq 2.0$, where q_1 is a momentum of the first combustion-supporting gas ejected per unit time from the first combustion-supporting gas ejection hole, and q_2 is a momentum of the second combustion-supporting gas ejected per unit time from the second combustion-supporting gas ejection hole.

30 **[0011] [3]**

The burner according to [1] or [2], further comprising a burner body having a double-pipe structure formed by the fuel gas supply pipe and the first combustion-supporting gas supply pipe.

35 **[0012] [4]**

The burner according to any one of [1] to [3], wherein

the fuel gas ejection hole is formed on an inner circumferential surface of the tip of the fuel gas supply pipe,

$d_1 < d_2$ at a position where $5 \times d_1 \leq L_1 \leq 10 \times d_1$, and

$\{(D_1 - d_1)/D_1\} \times 100 \leq 20$,

5 where d_1 is an inner diameter and D_1 is an outer diameter of the fuel gas supply pipe at the tip, and d_2 is an inner diameter at a position that is a distance L_1 from the tip.

[0013] [5]

The burner according to any one of [1] to [4], wherein

10 the first combustion-supporting gas ejection hole is formed on an inner circumferential surface of the tip of the first combustion-supporting gas supply pipe,

$d_3 < d_4$ at a position where $5 \times d_3 \leq L_2 \leq 10 \times d_3$,

15 where d_3 is an inner diameter of the first combustion-supporting gas supply pipe at the tip and d_4 is an inner diameter at a position that is a distance L_2 from the tip,

the tip of the fuel gas supply pipe is located closer to a base end than the tip of the first combustion-supporting gas supply pipe, and

$L_3 < 5 \times d_3$,

20 where L_3 is a distance from the tip of the fuel gas supply pipe to the tip of the first combustion-supporting gas supply pipe.

[0014] [6]

The burner according to any one of [1] to [5], further comprising

25 a burner body including the fuel gas supply pipe and the first combustion-supporting gas supply pipe; and

a burner block having an opening in which the burner body is disposed, wherein

$D_4 \leq D_5 \leq 1.1 \times D_4$,

30 where D_4 is a maximum outer diameter of the first combustion-supporting gas supply pipe at a portion thereof disposed at the opening, and D_5 is an inner diameter at a tip of the opening,

the tip of the first combustion-supporting gas supply pipe is located closer to a base end than the tip of the opening, and

$0.2 \leq \{(D_5/2)^2 \times \pi\} \div L_4^2 \leq 0.5$,

35 where L_4 is a distance from the tip of the opening to the tip of the first combustion-supporting gas supply pipe.

[0015] [7]

A heating furnace having installed therein at least one of the burner according to any one of [1] to [6].

(Advantageous Effect)

- 5 [0016] According to the present disclosure, it is possible to provide a burner that uses ammonia as fuel and can suppress the generation of NO_x while ensuring radiation intensity and flame stability.

BRIEF DESCRIPTION OF THE DRAWINGS

- 10 [0017] In the accompanying drawings:

FIG. 1 is a cross-sectional view illustrating a heating furnace according to an embodiment of the present disclosure;

FIG. 2 is a partially enlarged view of the burner illustrated in FIG. 1;

- 15 FIG. 3 is a graph illustrating the relationship between the oxygen concentration of the oxidizer and the adiabatic theoretical flame temperature; and

FIG. 4 is a graph illustrating the relationship between the oxygen concentration of the oxidizer and the combustion rate.

20 DETAILED DESCRIPTION

[0018] Hereinafter, embodiments of the present disclosure will be illustrated with reference to the drawings.

- [0019] As illustrated in FIGS. 1 and 2, in one embodiment of the present disclosure, a heating furnace 7 has at least one burner 1. The heating furnace 7 has a furnace side wall 7a in which the burner 1 is installed. The burner 1 is embedded in the furnace side wall 7a. This arrangement of the burner 1 in the heating furnace 7 is not limiting. The burner 1 burns fuel gas in the internal space 7b of the heating furnace 7 to heat an object to be heated and to melt the object as necessary.

- 30 [0020] The burner 1 includes a fuel gas supply pipe 2a, a first combustion-supporting gas supply pipe 2b, and a second combustion-supporting gas supplier 6. The fuel gas supply pipe 2a supplies a fuel gas containing ammonia (preferably without premixing oxygen) and ejects the fuel gas from a fuel gas ejection hole 2b at a tip thereof. The first combustion-supporting gas supply pipe 2b is provided radially outward from the fuel gas supply pipe 2a so as to surround the fuel gas supply pipe 2a
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(preferably, as illustrated in the drawings, to surround the tip of the fuel gas supply pipe 2a, and so that a flow passage for the first combustion-supporting gas is formed between the outer circumferential surface of the fuel gas supply pipe 2a and the inner circumferential surface of the first combustion-supporting gas supply pipe 2b that is spaced apart from the outer circumferential surface over the entire circumference), and supplies a first combustion-supporting gas (preferably without premixing fuel) and ejects the first combustion-supporting gas from a first combustion-supporting gas ejection hole 2b1 at a tip thereof. The second combustion-supporting gas supplier 6 supplies a second combustion-supporting gas and ejects the second combustion-supporting gas from a second combustion-supporting gas ejection hole 6a so that the second combustion-supporting gas joins a burner flame downstream from the first combustion-supporting gas ejection hole 2b1. The oxygen concentration of a combustion-supporting gas that is a combination of the first combustion-supporting gas and the second combustion-supporting gas is 30 % or more, the oxygen concentration of the second combustion-supporting gas is 90 % or more, and $0.38 \leq (V_1 + V_2)/V_3 \leq 1.1$, where V_1 is the volumetric flow rate of oxygen at the first combustion-supporting gas ejection hole 2b1, V_2 is the volumetric flow rate of oxygen at the second combustion-supporting gas ejection hole 6a, and V_3 is the volumetric flow rate of ammonia at the fuel gas ejection hole 2b.

[0021] According to the above configuration, the combustion-supporting gas, which is the sum of the first combustion-supporting gas and the second combustion-supporting gas, has an oxygen concentration of 30 % or more, so that ammonia can be used as the fuel gas while ensuring radiation intensity and flame stability. Furthermore, since the combustion-supporting gas has an oxygen concentration of 30 % or more, the oxygen concentration of the second combustion-supporting gas is 90 % or more, and $0.38 \leq (V_1 + V_2)/V_3 \leq 1.1$, the first combustion-supporting gas creates a reducing combustion state in which ammonia decomposes into nitrogen molecules and hydrogen molecules ($\text{NH}_3 \rightarrow 0.5\text{N}_2 + 1.5\text{H}_2$), thereby suppressing the generation of fuel NO_x (NO_x derived from N in the fuel gas). Furthermore, by the combination of the second combustion-supporting gas with the burner flame downstream from the first combustion-supporting gas ejection hole 2b1, the hydrogen molecules can be burned (preferably completely combusted) while suppressing the generation of thermal NO_x (NO_x derived from N in the second

combustion-supporting gas). Therefore, it is possible to realize a burner 1 that uses ammonia as fuel gas and can suppress the generation of NO_x while ensuring radiation intensity and flame stability. The fuel gas is not particularly limited as long as it contains ammonia, but the fuel gas preferably
5 contains ammonia as a main component (i.e., the ammonia component is more than 50 % and is 100 % or less). The first combustion-supporting gas is not particularly limited as long as it has an oxygen concentration that satisfies the aforementioned conditions, but oxygen-enriched air is preferably used. The fuel gas supply pipe 2a preferably surrounds the central axis of the first
10 combustion-supporting gas supply pipe 2b as illustrated in the drawings and more preferably is provided coaxially with the first combustion-supporting gas supply pipe 2b as illustrated in the drawings. In the present embodiment, the inner and outer circumferential surfaces of the fuel gas supply pipe 2a at the tip thereof and the inner and outer circumferential surfaces of the first
15 combustion-supporting gas supply pipe 2b at the tip thereof are each circular, but this example is not limiting.

[0022] The radiation intensity and flame stability of the burner 1 are related to the flame temperature and combustion rate, which in turn are related to the oxygen concentration of the combustion-supporting gas. For example, FIG. 3
20 illustrates how the oxygen concentration of the oxidizer (combustion-supporting gas) relates to the adiabatic theoretical flame temperature of the fossil fuel (methane) and ammonia, and FIG. 4 illustrates how the oxygen concentration of the oxidizer (combustion-supporting gas) relates to the combustion rate of the fossil fuel (methane) and ammonia. Thus,
25 ammonia has a lower flame temperature and combustion rate than fossil fuels. In view of the above, it has been found that by setting the oxygen concentration of the combustion-supporting gas to 30 % or more, radiation intensity and flame stability sufficient for practical use in industrial furnaces can be ensured.

[0023] A comparison of the chemical equations for CH₄ (methane) and NH₃ (ammonia), which are the main components of common fossil fuels, during burning is as follows.

- (1) $\text{CH}_4 + 2\text{O}_2 + 8\text{N}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + 8\text{N}_2$
(2) $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$
35 (3) $\text{NH}_3 + 0.75\text{O}_2 + 3\text{N}_2 \rightarrow 1.5\text{H}_2\text{O} + 3.5\text{N}_2$
(4) $\text{NH}_3 + 0.75\text{O}_2 \rightarrow 1.5\text{H}_2\text{O} + 0.5\text{N}_2$

Equation (1) represents the case in which CH_4 is burned in air.

Equation (2) represents the case in which CH_4 is burned in oxygen.

Equation (3) represents the case in which NH_3 is burned in air.

Equation (4) represents the case in which NH_3 is burned in oxygen.

5 **[0024]** The CO_2 and H_2O contained on the right side of each equation are known as radiative gases, and these gases contribute to the radiative performance of the combustion flame. A comparison of the equations indicates that the concentrations of the respective radiative gases are as follows, and that changing the oxidizer from air to oxygen improves the radiation
10 performance of the flame. However, in equation (2), the CO_2 concentration in the exhaust gas increases. In equation (3), the CO_2 concentration is zero, and the concentration of the radiative gas is greater than in equation (1). Furthermore, in equation (4), in which the oxidant is changed from air to oxygen, the concentration of the radiative gas is further improved. Therefore,
15 it is clear that increasing the oxygen concentration of the oxidizer is effective for ammonia, which has a low flame temperature.

[Table 1]

	Concentration (%)	
	CO_2	H_2O
Equation (1): CH_4 — air combustion	9.1	18.2
Equation (2): CH_4 — oxygen combustion	33.3	66.7
Equation (3): NH_3 — air combustion	0	30
Equation (4): NH_3 — oxygen combustion	0	75

[0025] In the burner 1, $0.1 \leq q_1/q_2 \leq 2.0$, where q_1 is the momentum of the
20 first combustion-supporting gas ejected per unit time from the first combustion-supporting gas ejection hole 2b1, and q_2 is the momentum of the second combustion-supporting gas ejected per unit time from the second combustion-supporting gas ejection hole 6a. Here, for example, q_1 is $q_1 = m_1 v_1$, where m_1 the mass of the first combustion-supporting gas ejected per
25 unit time from the first combustion-supporting gas ejection hole 2b1, and v_1 is the flow velocity of the first combustion-supporting gas at the first combustion-supporting gas ejection hole 2b1. For example, q_2 is $q_2 = m_2 v_2$, where m_2 is the mass of the second combustion-supporting gas ejected per unit time from the second combustion-supporting gas ejection hole 6a, and v_2 is
30 the flow velocity of the second combustion-supporting gas at the second

combustion-supporting gas ejection hole 6a. According to the above configuration, when the second combustion-supporting gas combines with the burner flame, the external atmosphere (such as the atmosphere inside the furnace) can be entrained into the second combustion-supporting gas, thereby preventing an excessive local rise in the temperature of the burner flame, and as a result, suppressing the generation of NO_x . Excess oxygen in the external atmosphere can also be used for combustion.

[0026] The burner 1 has a burner body 2 having a double-pipe structure formed by the fuel gas supply pipe 2a and the first combustion-supporting gas supply pipe 2b. According to the above configuration, radiation intensity and flame stability can be ensured with a simple structure.

[0027] The fuel gas ejection hole 2b is formed on the inner circumferential surface of the tip of the fuel gas supply pipe 2a, $d_1 < d_2$ at a position where $5 \times d_1 \leq L_1 \leq 10 \times d_1$, and $\{(D_1 - d_1)/D_1\} \times 100 \leq 20$, where d_1 is an inner diameter and D_1 is an outer diameter of the fuel gas supply pipe 2a at the tip, and d_2 is an inner diameter at a position that is a distance L_1 from the tip. According to the above configuration, since $d_1 < d_2$ at the position where $5 \times d_1 \leq L_1 \leq 10 \times d_1$, the flow passage of the fuel gas near the fuel gas ejection hole 2b narrows toward the fuel gas ejection hole 2b, causing the supply pressure of the fuel gas to increase toward the fuel gas ejection hole 2b. As a result, the supply pressure of the fuel gas at the fuel gas ejection hole 2b is made uniform, thereby improving the uniformity of the amount of fuel gas ejected from the fuel gas ejection hole 2b. Furthermore, since $\{(D_1 - d_1)/D_1\} \times 100 \leq 20$, the distance between the outer circumferential surface of the flow passage of the fuel gas and the inner circumferential surface of the flow passage of the first combustion-supporting gas at the tip of the fuel gas supply pipe 2a becomes small enough for practical use, thereby enabling rapid mixing of the fuel gas and the first combustion-supporting gas. Therefore, good flame stability as a result of good mixing can be achieved.

[0028] The first combustion-supporting gas ejection hole 2b1 is formed on the inner circumferential surface of the tip of the first combustion-supporting gas supply pipe 2b, $d_3 < d_4$ at a position where $5 \times d_3 \leq L_2 \leq 10 \times d_3$, where d_3 is the inner diameter of the first combustion-supporting gas supply pipe 2b at the tip and d_4 is the inner diameter at a position that is a distance L_2 from the tip, the tip of the fuel gas supply pipe 2a is located closer to a base end than the tip of the first combustion-supporting gas supply pipe 2b, and $L_3 < 5 \times d_3$,

where L_3 is the distance from the tip of the fuel gas supply pipe 2a to the tip of the first combustion-supporting gas supply pipe 2b. According to the above configuration, since $d_3 < d_4$ at a position where $5 \times d_3 \leq L_2 \leq 10 \times d_3$, the flow passage of the first combustion-supporting gas narrows toward the first combustion-supporting gas ejection hole 2b1, causing the supply pressure of the first combustion-supporting gas to increase toward the first combustion-supporting gas ejection hole 2b1. As a result, the supply pressure of the first combustion-supporting gas at the first combustion-supporting gas ejection hole 2b1 is made uniform, thereby improving the uniformity of the amount of first combustion-supporting gas ejected from the first combustion-supporting gas ejection hole 2b1. Furthermore, since the tip of the fuel gas supply pipe 2a is located closer to the base end than the tip of the first combustion-supporting gas supply pipe 2b, and $L_3 < 5 \times d_3$, a mixing chamber 3 can be formed while suppressing the possibility of backfire, thereby achieving even better mixing that results in even better flame stability. In the present embodiment, the fuel gas supply pipe 2a and the first combustion-supporting gas supply pipe 2b each extend linearly in parallel to the central axis at least in a range in which $0 \leq L_2 \leq 10 \times d_3$ is satisfied.

[0029] The burner 1 has a burner body 2 including the fuel gas supply pipe 2a and the first combustion-supporting gas supply pipe 2b, and a burner block 4 having an opening 4a in which the burner body 2 is disposed (preferably coaxially as illustrated in the drawings). $D_4 \leq d_5 \leq 1.1 \times D_4$, where D_4 is the maximum outer diameter of the first combustion-supporting gas supply pipe 2b at a portion thereof disposed at the opening 4a, and d_5 is the inner diameter at a tip of the opening 4a. The tip of the first combustion-supporting gas supply pipe 2b is located closer to the base end than the tip of the opening 4a, and $0.2 \leq \{(d_5/2)^2 \times \pi\} \div L_4^2 \leq 0.5$, where L_4 is the distance from the tip of the opening 4a to the tip of the first combustion-supporting gas supply pipe 2b. According to the above configuration, $D_4 \leq d_5 \leq 1.1 \times D_4$, the tip of the first combustion-supporting gas supply pipe 2b is located closer to the base end than the tip of the opening 4a, and $0.2 \leq \{(d_5/2)^2 \times \pi\} \div L_4^2 \leq 0.5$. Consequently, the opening 4a of the burner block 4 forms a good combustion chamber 5 while protecting the burner body 2 from radiant heat from the installation environment, such as an industrial furnace. The burner 1 is not limited to a configuration having the burner block 4 and may, for example, be configured to have a water-cooled jacket instead of or in addition to the

burner block 4. In the present embodiment, the opening 4a is configured as a circular through-hole, but this configuration is not limiting.

[0030] The second combustion-supporting gas supplier 6 is configured by the burner block 4, the burner block 4 has a second combustion-supporting gas supply path 4b for supplying the second combustion-supporting gas, and the tip of the second combustion-supporting gas supply path 4b forms a second combustion-supporting gas ejection hole 6a. According to the above configuration, the second combustion-supporting gas supplier 6 can be realized with a simple structure. In the present embodiment, the second combustion-supporting gas supply path 4b extends linearly and at an inclination with respect to the central axis. In the present embodiment, the inner circumferential surface (second combustion-supporting gas ejection hole 6a) at the tip of the second combustion-supporting gas supply path 4b is circular, but this example is not limiting. In the present embodiment, the second combustion-supporting gas ejection hole 6a is located vertically below the opening 4a, but this example is not limiting.

[0031] A configuration may be adopted in which $(0.06 \times V_3) \times 0.5 \leq L_5 \leq (0.06 \times V_3) \times 1.5$, where L_5 is the distance between the fuel gas ejection hole 2b and the point (preferably the intersection point) on the central axis of the first combustion-supporting gas supply pipe 2b closest to the axial center of the second combustion-supporting gas supply path 4b. According to the above configuration, the NO_x suppression effect due to the reducing combustion state can be easily obtained.

[0032] The tip of the opening 4a and the second combustion-supporting gas ejection hole 6a are arranged in parallel on the tip surface of the burner block 4 (i.e., the tip of the opening 4a is provided radially outward from the second combustion-supporting gas ejection hole 6a, and the second combustion-supporting gas ejection hole 6a is provided radially outward from the tip of the opening 4a). When the distance between the central axis of the opening 4a on the tip end surface of the burner block 4 and the axis of the second combustion-supporting gas ejection hole 6a is defined as L_6 , there are no particular limitations on L_6 , but setting L_6 as large as possible facilitates achievement of the NO_x suppression effect due to the reducing combustion state.

[0033] Although embodiments of the present disclosure have been described above, the present disclosure is not limited to the above-described

embodiments, and the above-described embodiments can be modified in various ways without departing from the scope of the present disclosure.

REFERENCE SIGNS LIST

5	[0034]	1	Burner
		2	Burner body
		2a	Fuel gas supply pipe
		2a1	Fuel gas ejection hole
		2b	First combustion-supporting gas supply pipe
10		2b1	First combustion-supporting gas ejection hole
		3	Mixing chamber
		4	Burner block
		4a	Opening
		4b	Second combustion-supporting gas supply path
15		5	Combustion chamber
		6	Second combustion-supporting gas supplier
		6a	Second combustion-supporting gas ejection hole
		7	Heating furnace
		7a	Furnace side wall
20		7b	Internal space
		d ₁	Inner diameter
		d ₂	Inner diameter
		d ₃	Inner diameter
		d ₄	Inner diameter
25		d ₅	Inner diameter
		D ₁	Outer diameter
		D ₂	Outer diameter
		D ₃	Outer diameter
		D ₄	Outer diameter
30		L ₁	Distance
		L ₂	Distance
		L ₃	Distance
		L ₄	Distance
		L ₅	Distance
35		L ₆	Distance
		O	Central axis

P Axial center

CLAIMS

[Claim 1] A burner, comprising:

5 a fuel gas supply pipe configured to supply a fuel gas containing ammonia and eject the fuel gas from a fuel gas ejection hole at a tip thereof;

a first combustion-supporting gas supply pipe provided radially outward from the fuel gas supply pipe so as to surround the fuel gas supply pipe and configured to supply a first combustion-supporting gas and eject the first combustion-supporting gas from a first combustion-supporting gas ejection hole at a tip thereof; and

10 a second combustion-supporting gas supplier configured to supply a second combustion-supporting gas and eject the second combustion-supporting gas from a second combustion-supporting gas ejection hole so that the second combustion-supporting gas joins a burner flame downstream from the first combustion-supporting gas ejection hole, wherein

an oxygen concentration of a combustion-supporting gas that is a combination of the first combustion-supporting gas and the second combustion-supporting gas is 30 % or more,

20 an oxygen concentration of the second combustion-supporting gas is 90 % or more, and

$0.38 \leq (V_1 + V_2)/V_3 \leq 1.1$, where V_1 is a volumetric flow rate of oxygen at the first combustion-supporting gas ejection hole, V_2 is a volumetric flow rate of oxygen at the second combustion-supporting gas ejection hole, and V_3 is a volumetric flow rate of ammonia at the fuel gas ejection hole.

[Claim 2] The burner according to claim 1, wherein $0.1 \leq q_1/q_2 \leq 2.0$, where q_1 is a momentum of the first combustion-supporting gas ejected per unit time from the first combustion-supporting gas ejection hole, and q_2 is a momentum of the second combustion-supporting gas ejected per unit time from the second combustion-supporting gas ejection hole.

[Claim 3] The burner according to claim 1, further comprising a burner body having a double-pipe structure formed by the fuel gas supply pipe and the first combustion-supporting gas supply pipe.

[Claim 4] The burner according to claim 1, wherein

the fuel gas ejection hole is formed on an inner circumferential surface of the tip of the fuel gas supply pipe,

$d_1 < d_2$ at a position where $5 \times d_1 \leq L_1 \leq 10 \times d_1$, and

5 $\{(D_1 - d_1)/D_1\} \times 100 \leq 20$,

where d_1 is an inner diameter and D_1 is an outer diameter of the fuel gas supply pipe at the tip, and d_2 is an inner diameter at a position that is a distance L_1 from the tip.

10 [Claim 5] The burner according to claim 1, wherein

the first combustion-supporting gas ejection hole is formed on an inner circumferential surface of the tip of the first combustion-supporting gas supply pipe,

$d_3 < d_4$ at a position where $5 \times d_3 \leq L_2 \leq 10 \times d_3$,

15 where d_3 is an inner diameter of the first combustion-supporting gas supply pipe at the tip and d_4 is an inner diameter at a position that is a distance L_2 from the tip,

the tip of the fuel gas supply pipe is located closer to a base end than the tip of the first combustion-supporting gas supply pipe, and

20 $L_3 < 5 \times d_3$,

where L_3 is a distance from the tip of the fuel gas supply pipe to the tip of the first combustion-supporting gas supply pipe.

[Claim 6] The burner according to claim 1, further comprising

25 a burner body including the fuel gas supply pipe and the first combustion-supporting gas supply pipe; and

a burner block having an opening in which the burner body is disposed, wherein

$D_4 \leq D_5 \leq 1.1 \times D_4$,

30 where D_4 is a maximum outer diameter of the first combustion-supporting gas supply pipe at a portion thereof disposed at the opening, and D_5 is an inner diameter at a tip of the opening,

the tip of the first combustion-supporting gas supply pipe is located closer to a base end than the tip of the opening, and

35 $0.2 \leq \{(D_5/2)^2 \times \pi\} \div L_4^2 \leq 0.5$,

where L_4 is a distance from the tip of the opening to the tip of the first

combustion-supporting gas supply pipe.

[Claim 7] A heating furnace having at least one burner according to any one of claims 1 to 6 installed therein.