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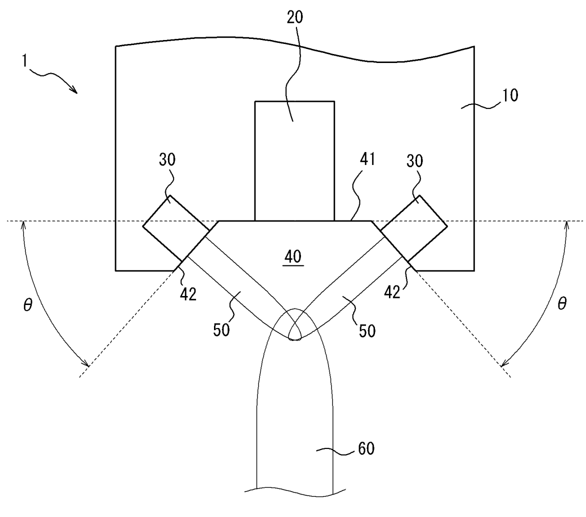
(54) HEATING DEVICE AND HEATING METHOD

(57) Provided is a heating device which can stably hold flame without flame off even when a discharge speed is high, and thus can perform heating with extremely high efficiency. The heating device comprises a burner, wherein the burner comprises: a main burner part having a fuel gas nozzle configured to discharge fuel gas and an air nozzle configured to discharge air for combustion; and a sub burner part positioned further outward than the main burner part and configured to combust the fuel gas discharged from the main burner part.

FIG. 1



Description

TECHNICAL FIELD

[0001] The disclosure relates to a heating device comprising a burner, in particular, a heating device which can stably hold flame without flame off when a discharge speed is high, and thus can perform heating with extremely high efficiency. Further, the disclosure relates to a heating method using the heating device.

BACKGROUND

[0002] Methods of heating an object include various methods such as hot blast heating, infrared heating, heating by an electrical heater, and induction heating. Among them, heating by a burner is extremely commonly used for various uses.

[0003] FIG. 8 is a schematic diagram illustrating an example of a conventionally used premixing combustion burner. In a premixing combustion burner 100, flammable fuel gas 101 and air 102 are mixed in advance in the inside of the premixing combustion burner 100 into mixed gas, and the mixed gas is discharged from the premixing combustion burner 100 and burnt to form flame 103.

[0004] In direct heating using such flame formed by a burner, the amount of heat transfer Q from the flame to a surface of an object to be heated is proportional to the heat transfer coefficient α and the heat transfer coefficient α depends on the discharge speed of flame V_0. For example, for a burner having a circular opening, the heat transfer coefficient α is proportional to $V_0^{1/2}$. Further, for a line burner which has a plurality of nozzles disposed on a straight line, the heat transfer coefficient α is proportional to $V_0^{0.58}$. Therefore, to improve the efficiency of heating by a burner, an increase in the discharge speed is required.

[0005] When the flow speed of fuel gas and air is simply increased to increase the discharge speed, however, flame becomes unstable. When the flow speed is further increased, the balance is lost between the combustion speed and the gas flow speed, causing flame to be blown away to the downstream and quenched, which is called blowoff. Therefore, a conventional burner cannot have a significantly increased discharge speed, which limits improvement of heating efficiency.

[0006] As a method to stabilize flame and prevent blowoff, JP2013-194991 A (PTL 1) proposes a method using a burner comprising a main burner and a pilot flame burner which assists combustion in the main burner.

CITATION LIST

Patent Literature

[0007] PTL 1: JP 2013-194991 A

SUMMARY

(Technical Problem)

[0008] The burner of PTL 1 can stabilize flame and increase flame temperature. However, the burner proposed in PTL 1 is insufficient in terms of the aforementioned improvement of the discharge speed. Thus, to improve the heating efficiency, the development of a heating device is demanded comprising a burner which can be stably used at a further high discharge speed.

[0009] It would thus be helpful to provide a heating device which can stably hold flame without flame off when a discharge speed is high, and thus can perform heating with extremely high efficiency. Further, it could also be helpful to provide a heating method using the heating device.

(Solution to Problem)

[0010] We accordingly conducted an investigation and found that a burner comprising a main burner part and a sub burner part which are disposed in a particular positional relationship can stably hold flame when a discharge speed is extremely high such as 50 Nm/s or more. The disclosure is based on the finding and has the following primary features.

1. A heating device comprising a burner, wherein the burner comprises:

    a main burner part having a fuel gas nozzle configured to discharge fuel gas and an air nozzle configured to discharge air for combustion; and a sub burner part positioned further outward than the main burner part and configured to combust the fuel gas discharged from the main burner part.

2. The heating device according to 1., wherein the main burner part comprises a pressure equalizing chamber on the upstream side of one or both of the fuel gas nozzle and the air nozzle.
3. The heating device according to 1. or 2., wherein the fuel gas nozzle and the air nozzle have a straight tube structure.
4. The heating device according to any one of 1. to 3.,
wherein the burner comprises at its end a recessed part having a bottom part and a tapered part, the tapered part gradually widening from the bottom part to the end of the burner,
wherein the main burner part is disposed on the bottom part, and
wherein the sub burner part is disposed on the tapered part.
5. The heating device according to 4., wherein the bottom part makes an angle θ of 20° or more with respect to the tapered part.
6. The heating device according to any one of 1. to 5., wherein the sub burner part is a surface combustion burner.
7. The heating device according to 4. or 5.,
wherein the sub burner part has a sub burner nozzle selected from a tubular nozzle with a diameter d and a slit nozzle with a width d in the short side direction, and
wherein the sub burner nozzle is disposed so that its end is provided further inward by a distance of d or more and 15d or less than a surface of the tapered part.
8. The heating device according to any one of 1. to 7., comprising a flow rate adjuster capable of independently adjusting a flow rate in the main burner part and a flow rate in the sub burner part.
9. A heating method using the heating device according to any one of 1. to 8.
10. The heating method according to 9., wherein each of the fuel gas and the air for combustion, which are discharged from the main burner part, has a discharge speed of 50 Nm/s or more.
11. The heating method according to 9. or 10., wherein a ratio of F1 : F2 is 70 : 30 to 85 : 15, F1 being a flow rate of the fuel gas which is discharged from the main burner part, F2 being a flow rate of the fuel gas for sub burner flame which is discharged from the sub burner part.

(Advantageous Effect)

[0011] Our heating device can stably hold flame without flame off even when a discharge speed is high, and thus perform heating with extremely high efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 is a schematic diagram illustrating the structure of a burner in one embodiment.
FIG. 2 is a schematic diagram illustrating the structure of a main burner part in one embodiment.
FIG. 3 is a schematic diagram illustrating the structure of a sub burner part in one embodiment.
FIG. 4 is a schematic diagram illustrating the structure of a sub burner part in another embodiment.
FIG. 5 illustrates a discharge speed in the burners in Example and Comparative Examples.
FIG. 6 illustrates heating power in the burners in Example and Comparative Examples.
FIG. 7 illustrates a measurement example of temperature distribution in the burners of Comparative Example 1 and Example 1.
FIG. 8 is a schematic diagram illustrating an example of a conventional premixing combustion burner.

DETAILED DESCRIPTION

[0013] Next, detailed description is given below. The following provides a description of preferred embodiments and the disclosure is by no means limited to the description.

[0014] The disclosed heating device is a heating device comprising a burner, in which the burner comprises a main burner part and a sub burner part. The main burner part comprises a fuel gas nozzle configured to discharge fuel gas and an air nozzle configured to discharge air for combustion. Fuel gas and air which are discharged from the main burner part are combusted with each other to thereby form flame for heating an object to be heated. The sub burner part has a function of igniting the fuel gas discharged from the main burner part.

[0015] It is important that the sub burner part is disposed further outward than the main burner part. Such a positional relationship enables stably held flame when a discharge speed is high, compared with other positional relationships. As stated above, the amount of heat transfer Q from flame to a surface of an object to be heated is proportional to the heat transfer coefficient α and the heat transfer coefficient α is larger as the discharge speed of flame V_0 is increased. Therefore, our heating device can hit flame at a high speed against a surface of an object to be heated to thereby perform heating with extremely high efficiency. As the result, the object to be heated can be heated to higher temperature more rapidly. Further, the heating device can achieve specific heating temperature with a less amount of fuel gas. Moreover, the heating device can have a high discharge speed, and thus have flame reaching to a distant position. Therefore, the burner can be located apart from an object to be heated, thus improving the flexibility of design of the device.

[0016] In particular, steelmaking processes often need to heat an object to be heated which is apart from a burner. Therefore, our heating device can be very preferably used as a heating device for steelmaking processes for heating steelmaking raw materials. The heating device for steelmaking processes includes an ignition device of a sintering machine which is used, for example, for manufacturing sintered ores. When our heating device is used as a heating device for steelmaking processes, the burner is preferably a line burner comprising a plurality of nozzles disposed straightly.

[0017] The aforementioned positional relationship enables stably held flame when a discharge speed is high, which is assumed to be because of the following reasons. Specifically, as proposed in PTL 1, when the fuel gas nozzle and the air for combustion nozzle are disposed so as to sandwich the pilot flame burner, and a discharge direction of fuel gas is set so as to cross a discharge direction of air for combustion, a vortex occurs, increasing kinetic energy loss due to flow turbulence. Thus a high flow speed cannot be maintained. On the other hand, our technique can prevent flow turbulence of main fuel gas and air for combustion by disposing the sub burner part further outward than the main burner part in the burner, thus maintaining a high flow speed. Further, when directions of fuel gas and air for combustion which are discharged from the main burner part are parallel to one another, flow turbulence can be further prevented, thus maintaining a higher flow speed.

[0018] In addition, when the fuel gas nozzle is in a center part and the pilot flame burners are disposed on the outside of the center part and the air for combustion nozzles are disposed on the further outside of the pilot flame burners, fuel gas is necessary to be discharged toward the pilot flame on the both sides, thus requiring to set the fuel gas nozzles on the both sides, increasing the number of the nozzles. Then, when a discharge speed is intended to be increased, the diameter of each nozzle becomes small to thereby significantly decrease the gas speed after discharge, which makes it impossible to maintain a high flow speed after discharge. On the other hand, our technique does not need to divide fuel gas to the both sides, and thus a high flow speed can be maintained.

[Fuel gas]

[0019] Fuel gas is not limited and any flammable gas can be used as the fuel gas. As the fuel gas, for example, natural gas and LPG (liquefied petroleum gas) are typically available. When the heating device is used in a steelworks, process gas produced as a by-product can be used as the fuel gas. As the process gas, process gas containing coke oven gas is preferably used. As the process gas containing coke oven gas, for example, coke oven gas itself (i.e., gas containing only coke oven gas) and M gas in which coke oven gas and blast furnace gas are mixed are preferably used.

[0020] Next, a more detailed description is given below with reference to the drawings.

[0021] FIG. 1, which is a schematic diagram of a burner 1 in one embodiment, illustrates a cross sectional structure of the burner 1. The burner 1 comprises a burner body 10, and a main burner part 20 and a sub burner part 30 which are provided in the burner body 10. The burner 1 has at its end (the side on which flame is formed) a recessed part 40, and the recessed part 40 has a bottom part 41 and a tapered part 42 , the tapered part gradually widening from the bottom part 41 to the end of the burner 1.

[Main burner part]

[0022] FIG. 2 is a schematic diagram illustrating the structure of the main burner part 20 in one embodiment. The main burner 20 comprises a fuel gas nozzle 21 which discharges fuel gas and an air nozzle 22 which discharges air for combustion. One fuel gas nozzle 21 is provided at the center of the bottom part 41. Two air nozzles 22 are provided symmetrically so as to sandwich the fuel gas nozzle 21. The example illustrated in FIG. 2 illustrates a cross section of one burner, but when a wide object is heated, a plurality of burners is preferably disposed in a perpendicular direction to the paper surface so as to be a line burner.

[0023] The fuel gas is supplied as illustrated by an arrow mark G, and discharged from the fuel gas nozzle 21. The air for combustion is supplied as illustrated by an arrow mark A, and discharged from the air nozzle 22. The fuel gas is not ignited at the discharge, but as illustrated in FIG. 1, it is ignited by a sub burner flame 50 formed by the sub burner part 30 to thereby form flame 60.

[0024] The shapes of the fuel gas nozzle 21 and the air nozzle 22 are not limited and they have any shape. As illustrated in FIG 2, however, the nozzles preferably have a straight tube structure, which has no cone-like structure on its end.

Using a nozzle with a straight tube structure, the discharge speed can be further increased to make the heat transfer coefficient larger on a surface to be heated. As the result, heating efficiency can be further improved. This is because the nozzle with a straight tube structure has little energy loss due to formation of a vortex, compared with when a nozzle which forms a revolving flow is used, and thus a decrease in the gas speed after discharge is reduced.

[0025] The diameters (hereinafter, referred to as nozzle diameter) of the fuel gas nozzle 21 and the air nozzle 22 are preferably determined so that the discharge speed in a flow rate range in ordinary use may be 50 Nm/s to 80 Nm/s in order to increase the heating efficiency of the burner. The discharge speed at maximum combustion is preferably 150 Nm/s or less. The definition of the discharge speed will be discussed later.

[0026] A specific diameters of the fuel gas nozzle 21 and the air nozzle 22 are not limited, but when the diameter is 3 mm or more, the reduction in the gas speed after the gas discharge from the nozzle can be further prevented. Therefore, the diameter is preferably 3 mm or more, and more preferably 5 mm or more. On the other hand, an upper limit of the diameter is not limited, but when the diameter is 30 mm or less, the heat load on the burner is in a more preferable range and thus the life of the burner can be extended. Further, by providing many nozzles with a small diameter such as 30 mm or less, uniform heating can be performed, compared with when a small number of nozzles with a large diameter are provided. Therefore, the diameter is preferably 30 mm or less. The diameter of the fuel gas nozzle 21 may or may not be the same as the diameter of the air nozzle 22.

[0027] The interval (nozzle pitch) L_1 between the fuel gas nozzle 21 and the air nozzle 22 preferably satisfies $2\ d_{NG} \leq L_1 \leq 15\ d_{NA}$, where d_{NG} is a diameter of the fuel gas nozzle 21 and d_{NA} is a diameter of the air nozzle 22. When a plurality of burners is disposed to make a line burner, the interval (nozzle pitch) L_2 between the fuel gas nozzles of the burners preferably satisfies $2\ d_{NG} \leq L_2 \leq 15\ d_{NA}$. When the conditions are satisfied, the combustion stability is further improved and the reduction in the gas speed is further prevented.

[Pressure equalizing chamber]

[0028] The main burner part 20 comprises pressure equalizing chambers 23 on the upstream side of each of the fuel gas nozzle 21 and the air nozzles 22, and comprises, on the opposite side (upstream side) of the nozzles of the pressure equalizing chambers 23, perforated plates 24 having an opening through which fuel gas or air passes. With such a pressure equalizing chamber 23, gas can be discharged more uniformly, thus further stabilizing flame and further increasing the discharge speed. The pressure equalizing chamber 23 may be provided only on the upstream side of either the fuel gas nozzle 21 or the air nozzles 22, but as illustrated in FIG. 2, the pressure equalizing chamber is preferably provided on the upstream side of both the fuel gas nozzle 21 and the air nozzles 22. As used herein, the pressure equalizing chamber is a structure provided on the upstream side of the nozzle to relieve an effect of the fluctuation of gas supply pressure. As illustrated in FIG. 2, the pressure equalizing chamber comprises a plate (diaphragm plate) having one or more openings on the upstream side of the nozzle, and a space between the diaphragm plate and the nozzle. The upstream side of the diaphragm plate is connected to the space only through the opening of the diaphragm plate. The total area of the openings of the diaphragm plate is smaller than the cross-sectional area at a plane perpendicular to the discharge direction of the nozzle in the space. Further, the total area of the opening of the nozzle is smaller than the cross-sectional area at a plane perpendicular to the discharge direction of the nozzle in the space.

[Sub burner part]

[0029] As described above, the sub burner part has a function of igniting fuel gas discharged from the main burner part and combusting the fuel gas. The fuel gas discharged from the main burner part is ignited by flame (sub burner flame) formed by the sub burner part. Therefore, the sub burner part typically comprises a fuel gas outlet for sub burner flame and an air outlet for sub burner flame to form sub burner flame. The air for sub burner flame is used to combust the fuel gas for sub burner flame, thus forming sub burner flame. In the following description, the "fuel gas for sub burner flame" may be referred to simply as "fuel gas", and the "air for sub burner flame" may be referred to simply as "air".

[0030] As described above, our heating device comprises the sub burner part further outward than the main burner part to combust the fuel gas discharged from the main burner part. Thus, our heating device can hold flame stably under conditions in which a discharge speed of the fuel gas from the main burner is high. Therefore, our burner is advantageous in that the burner does not need to have a combustion chamber structure to stably hold flame on the forward side of the main burner, i.e., a structure protruding forward from the burner to surround the main burner and the sub burner.

[0031] Further, our heating device holds flame of the main burner in a space forward in the gas discharge direction from the main burner. In publicly-known techniques, a combustion chamber structure or a cone-like structure made up of a refractory material to stably hold flame on the forward side of the main burner is provided to thereby hold flame in the inside of the structure and hold flame which touches a surface of the structure. However, our heating device can hold high-speed flame from the main burner without such a structure by holding flame of the main burner in the space using flame of the sub burner. To hold such flame, the intersection point of the gas discharge direction of the main burner part and the gas discharge direction of the sub burner part is preferably disposed in the space in front of the burner in the gas discharge direction or in an outer side of the recessed part of the burner (outside of the burner).

[0032] FIG. 3 is a schematic diagram illustrating the structure of a sub burner part 30 in one embodiment. In this example, the sub burner part 30 includes a surface combustion burner. The surface combustion burner has a porous plate 31 at its end and the porous plate 31 is supplied with fuel gas for sub burner flame and air for sub burner flame as illustrated by arrow marks G and A, respectively.

[0033] In our heating device, fuel gas and air are discharged from the main burner part 20 at a high speed , and thus a flow accompanied with the airflow is formed near the end of the burner 1, in particular, in the inside of the recessed part 40. For example, when the flow speed of gas discharged from the main burner part is 50 m/s, the flow speed of the accompanied flow is as high as 20 m/s to 30 m/s. Thus, sub burner flame 50 formed by the sub burner part 30 may be unstable. However, the surface combustion burner has an ignition point in the surface or the inside of the porous plate. Therefore, the sub burner flame can be stably held, not being affected by the accompanied flow.

[0034] As the porous plate 31, any plate member made up of a porous body can be used. The porous body can be made up of one or more materials selected from the group consisting of metal, alloy, and ceramic. As the porous plate 31, for example, a metal mesh (laminate of metal fibers) can be used. The surface of the porous plate 31 is preferably disposed on the same plane as that of the tapered part 42.

[0035] As illustrated in FIG. 1, fuel gas and air discharged from the main burner part 20 are ignited by the sub burner flame 50. Therefore, to ensure the ignition, the main burner part 20 and the sub burner part 30 are preferably disposed so that the discharge axis (discharge direction) of the main burner part 20 and the discharge axis (discharge direction) of the sub burner part 30 are crossed with each other in their extension lines. Specifically, the bottom part 41 and the tapered part 42 which form the recessed part 40 preferably make an angle θ of 20° or more. When θ is less than 20°, flame of the sub burner part is less likely to reach a gas flow discharged from the main burner part, thus tending to cause flame off. θ is preferably 30° or more. On the other hand, θ may have any upper limit, but typically, θ is preferably 80° or less, and more preferably 60° or less.

[0036] The distance between the main burner part and the sub burner part is determined so that flame (sub burner flame 50) of the sub burner part can reach the discharge flow from the main burner part. When the effective length of flame of the sub burner part is F, the distance of the flame of the sub burner part reaching in the direction parallel to the bottom part 41 is $F \cdot \sin\theta$. Thus, the main burner part and the sub burner part are disposed so that the distance between the edge position of the main burner and the center position of the sub burner part may be $F \cdot \sin\theta$ or less in the direction parallel to the bottom part 41. Specifically, when the effective length of flame of the sub burner part is 100 mm, the width of the main burner (distance between the outermost nozzles of the main burner part) is 50 mm, and $\theta = 30°$, the distance between the center of the main burner part and the center of the sub burner part is 75 mm or less. Considering the preferred range of θ, the distance between the center of the main burner part and the center of the sub burner part is preferably 60 mm to 110 mm. The effective length of flame can be determined, based on the measurement result of a flame temperature, as the length of a region having gas ignition temperature or more from the combustion surface or the tapered surface.

[0037] FIG. 4 is a schematic diagram illustrating an example of the structure of the sub burner part in another embodiment. In this embodiment, the sub burner part 30 has a tubular nozzle with a diameter d as a sub burner nozzle 32. The sub burner nozzle 32 has an outer tube and an inner tube which share a common axis. The inner tube is supplied with fuel gas for sub burner flame as illustrated by an arrow mark G, and the fuel gas for sub burner flame is discharged from the end of the inner tube. On the other hand, the outer tube is supplied with air for sub burner flame as illustrated by an arrow mark A, and the air for sub burner flame is discharged from the end of the outer tube.

[0038] The end of the sub burner nozzle 32 is provided further inward by a distance of d or more than a surface of the tapered part 42 as illustrated in FIG. 4. In other words, the distance from a surface of the tapered part 42 to the end of the sub burner nozzle 32 is d or more. The fuel gas for sub burner flame discharged from the sub burner nozzle 32 is ignited in a space 33 to form flame (sub burner flame) so that the flame may extend outward beyond a surface of the tapered part 42. The end of the sub burner nozzle 32 is thus at an inner position of the burner body 10, thereby preventing the aforementioned effect of an accompanied flow to enable sub burner flame to be stably held without using a surface combustion burner. When the sub burner part 30 has, as the sub burner nozzle 32, a slit nozzle with a width d in the short-side direction, the end of the sub burner nozzle 32 is also preferably provided further inward by a distance of d or more than a surface of the tapered part 42. To curb the effect of an accompanied flow, the distance from a surface of the tapered part 42 to the end of the sub burner nozzle 32 is preferably 2d or more. On the other hand, when the end of the sub burner nozzle 32 is provided further inward by a distance of 15d or more than a surface of the tapered part 42, flame temperature may be lowered. Therefore, the distance from a surface of the tapered part 42 to the end of the sub burner nozzle 32 is preferably 15d or less, and more preferably 4d or less.

[Discharge speed]

[0039] As described above, our heating device can stably hold flame without flame off when a discharge speed is high, and thus perform heating with extremely high efficiency. The discharge speed at use is not limited and can be any speed in a range where flame can be held, but in terms of heating efficiency, the discharge speeds of fuel gas and air discharged from the main burner part are preferably 50 Nm/s or more, more preferably 60 Nm/s or more, and further preferably 65 Nm/s or more. Such an extremely high discharge speed has not been achieved by conventional burners.

[0040] The discharge speed, which is a gas flow speed in the straight tube parts of the fuel gas nozzle and the air nozzle of the main burner part, is determined as follows: a discharge speed = a gas flow rate per unit time in a single nozzle / a cross-sectional area of the nozzle. For a nozzle without a straight tube part, the cross-sectional area of the nozzle is the cross-sectional area of the outlet part of the nozzle. When a burner with many nozzles or openings has a conical cone part in front of the nozzles as illustrated in FIG. 8, the discharge speed of the burner can be determined by dividing the sum of the flow rates of fuel gas and air which are discharged from the burner by the cross-sectional area in the outlet of the cone part.

[0041] The discharge speed of fuel gas is preferably roughly equivalent to the discharge speed of air for combustion. Specifically, the ratio of the discharge speed of fuel gas to the discharge speed of air for combustion (discharge speed ratio) is preferably 0.8 to 1.2. In a burner with a conical cone, the discharge speed ratio in the nozzle opening part in front of the cone is preferably 0.8 to 1.2.

[Flow rate ratio of fuel gas]

[0042] The ratio of the flow rate of fuel gas in the main burner part and the flow rate of fuel gas in the sub burner part (hereinafter, referred to as "flow rate ratio of fuel gas") significantly affects the stability and the heating ability of flame. Therefore, the heating device preferably comprises a flow rate adjuster capable of separately adjusting the flow rate of fuel gas in the main burner part and the flow rate of fuel gas in the sub burner part. Further, the content of air for combustion can be determined by multiplying the flow rate of fuel gas by the theoretical air content of the fuel gas and the air ratio. The heating device preferably comprises a flow rate adjuster capable of separately adjusting the flow rate of air for combustion in the main burner part and the flow rate of air for combustion in the sub burner part. The flow rate adjuster includes a flow adjusting valve.

[0043] When the sum of the flow rate of fuel gas in the main burner part and the flow rate of fuel gas of the sub burner part is 100 %, and the flow rate of fuel gas in the sub burner part is less than 15 %, a flame temperature is significantly lowered by an accompanied flow, which is likely to cause flame off in the main burner. Therefore, the flow rate of fuel gas in the sub burner part is preferably 15 % or more. In other words, a ratio F1 : F2 is preferably 85 : 15 or less ($F1 / F2 \leq 85 / 15$), where F1 is a flow rate of fuel gas discharged from the main burner part, and F2 is a flow rate of fuel gas for sub burner flame discharged from the sub burner part. On the other hand, when the flow rate of fuel gas of the sub burner part is too high, flame is stably held but flame of the main burner part becomes small, thus deteriorating heating ability. Therefore, the flow rate of fuel gas in the sub burner part is preferably 30 % or less. In other words, F1 : F2 is preferably 70 : 30 or more ($F1 / F2 \geq 70 / 30$).

EXAMPLES

[0044] To examine effects of a burner structure on the stability of flame, the following three types of burners were used to evaluate the maximum discharge speed which could hold flame without flame off.

(Comparative Example 1) a conventional typical premixing combustion burner as illustrated in FIG. 8
(Comparative Example 2) a burner illustrated in FIG. 1 of PTL 1

(Example 1) a burner illustrated in FIGS. 1 to 3

[0045] Example and Comparative Examples described above each have a burner with a width of 1 m in the direction perpendicular to the cross section illustrated in FIGS. 1 and 8. Table 1 lists the size of a nozzle and the cross-sectional area of a discharge part. Table 1 also lists the ratio of a flow rate of fuel gas in the main burner part and a flow rate of fuel gas in the sub burner part (flow rate ratio of fuel gas) in Comparative Example 2 and Example 1.

[0046] Comparative Example 1 used a slit-shaped nozzle which had a width of 10 mm and a length of 1 m, and had a cross-sectional shape illustrated in FIG. 8. Comparative Example 2 used 60 pairs of nozzles of FIG. 1 of PTL 1 which were disposed linearly over 1 m in the width direction of the burner. Each burner of PTL 1 had two fuel gas nozzles, and thus the number of the fuel gas nozzles was 120 in total. Example 1 used 50 pairs of nozzles of FIGS. 1 and 2 of the disclosure, i.e., 50 fuel gas nozzles, which were disposed linearly over 1 m in the width direction of the burner. When

50 pairs of nozzles were disposed in the burner of Comparative Example 2, flame was unstable. Therefore, 60 pairs of nozzles were disposed to stabilize flame.

[0047] Experiments were performed in a combustion furnace for experiments with a combustion space of 1.4 m × 1.4 m × 0.4 m. The flow rates of fuel gas and air for combustion were increased so as to keep a constant flow rate ratio of the fuel gas and the air for combustion, and the maximum discharge speed was measured which could hold flame without blowoff.

[0048] As the fuel gas, M gas (mixed gas of coke oven gas and blast furnace gas), which was a by-product in a steelworks, was used. The main components of the M gas were H_2: 26.5 %, CO: 17.6 %, CH_4: 9.1 %, and N_2: 30.9 %.

Table 1

	Nozzle width		Diameter of a fuel gas nozzle (Main burner part)	Number of fuel gas nozzles	Total cross-sectional area of a discharge part (cm^2)	Flow rate ratio of fuel gas*
	Straight tube part	Cone part				
Comparative Example 1	10 mm	100 mm	(Slit nozzle with a length of 1 m)		100 (Straight tube part)	-
Comparative Example 2	-	-	6 mm	120	33.8 (Main burner part)	75 : 25
Example 1	-	-	6 mm	50	14.1 (Main burner part)	75 : 25
*a ratio of a flow rate F1 of fuel gas in a main burner part and a flow rate F2 of fuel gas in a sub burner part (F1 : F2)						

[0049] The measurement results are illustrated in FIG. 5. In Comparative Example 1, when the flow speed (discharge speed) in the straight tube part of the nozzle was more than 30 Nm/s, flame was not held and blowoff was caused. The flow speed in the straight tube corresponds to 3 Nm/s in terms of a flow speed in the end of the cone part. In Comparative Example 2, when the flow speed (discharge speed) in the straight tube part of the nozzle was more than 40 Nm/s, flame was not held and blowoff was caused. On the other hand, Example 1, which had a condition of the discharge speed being more than 40 Nm/s, had stable flame. With the discharge speed being more than 100 Nm/s, flame became unstable. With the discharge speed being 120 Nm/s, blowoff was caused.

[0050] From the above results, it is found that our heating device can achieve stable combustion when a discharge speed is extremely high compared with in a conventional burner. When our heating device is actually used in industries at near the maximum flow speed which would cause no blowoff, the blowoff risk may be enhanced by fluctuations in the operation of a supply system. Therefore, the burner is preferably used with a flow speed being less than the maximum flow speed which would cause no blowoff. FIG. 5 illustrates an example of a flow speed in an actual ordinary use.

[0051] During the measurement, water-cooled chillers which simulated an object to be heated were disposed 0.4 m away from the burners so as to face the burners, and the heating power of the burners was evaluated on the basis of the temperature rise of the water. FIG. 6 illustrates the heating power of the burners of Example and Comparative Examples which had the same flow rate of fuel gas and the same air ratio. It is found that in Example 1, the heating power was extremely increased, compared with Comparative Example 1 and Comparative Example 2.

[0052] Further, during the measurement, the distribution of flame temperature in Comparative Example 1 and Example 1 was measured using a thermocouple, and according to the measurement, isotherms were created in a cross-sectional direction of the burners. FIG. 7 illustrates the results. Comparative Example 1 and Example 1 were measured at the same flow speed of fuel gas and the same air ratio. Comparative Example 1 had combustion in the inside of the cone in front of the burner, and much of the fuel gas was combusted before the fuel gas reached an object to be heated. On the other hand, in Example 1, the fuel gas discharged from the main burner was ignited by flame of the sub burner in the vicinity of the middle part between the burner and an object to be heated, and started to combust. Much fuel gas was combusted near the object to be heated. As the result, it is considered that in the burner of Example 1, flame collided against the object to be heated at high speed and transferred more energy to the surface to be heated, and thus, even though the gas temperature near the object to be heated appeared to be nearly equal between Comparative Example 1 and Example 1, the heating power was extremely increased in Example 1 as illustrated in FIG. 7.

REFERENCE SIGNS LIST

[0053]

1 burner

10 burner body
20 main burner part
21 fuel gas nozzle
22 air nozzle
23 pressure equalizing chamber
30 sub burner part
31 porous plate
33 space
40 recessed part
41 bottom part
42 tapered part
50 sub burner flame
60 flame

Claims

1. A heating device comprising a burner, wherein the burner comprises:

a main burner part having a fuel gas nozzle configured to discharge fuel gas and an air nozzle configured to discharge air for combustion; and
a sub burner part positioned further outward than the main burner part and configured to combust the fuel gas discharged from the main burner part.

2. The heating device according to claim 1, wherein the main burner part comprises a pressure equalizing chamber on an upstream side of one or both of the fuel gas nozzle and the air nozzle.

3. The heating device according to claim 1 or 2, wherein the fuel gas nozzle and the air nozzle have a straight tube structure.

4. The heating device according to any one of claims 1 to 3,
wherein the burner comprises at its end a recessed part having a bottom part and a tapered part, the tapered part gradually widening from the bottom part to the end of the burner,
wherein the main burner part is disposed on the bottom part, and
wherein the sub burner part is disposed on the tapered part.

5. The heating device according to claim 4, wherein the bottom part forms an angle θ of 20° or more with respect to the tapered part.

6. The heating device according to any one of claims 1 to 5, wherein the sub burner part is a surface combustion burner.

7. The heating device according to claim 4 or 5,
wherein the sub burner part has a sub burner nozzle selected from a tubular nozzle with a diameter d and a slit nozzle with a width d in a short side direction, and
wherein the sub burner nozzle is disposed so that its end is provided further inward by a distance of d or more and 15d or less than a surface of the tapered part.

8. The heating device according to any one of claims 1 to 7, comprising a flow rate adjuster capable of independently adjusting a flow rate in the main burner part and a flow rate in the sub burner part.

9. A heating method using the heating device according to any one of claims 1 to 8.

10. The heating method according to claim 9, wherein each of the fuel gas and the air for combustion, which are discharged from the main burner part, has a discharge speed of 50 Nm/s or more.

11. The heating method according to claim 9 or 10, wherein a ratio of F1 : F2 is 70 : 30 to 85 : 15, F1 being a flow rate of the fuel gas which is discharged from the main burner part, F2 being a flow rate of the fuel gas for sub burner flame which is discharged from the sub burner part.

FIG. 1

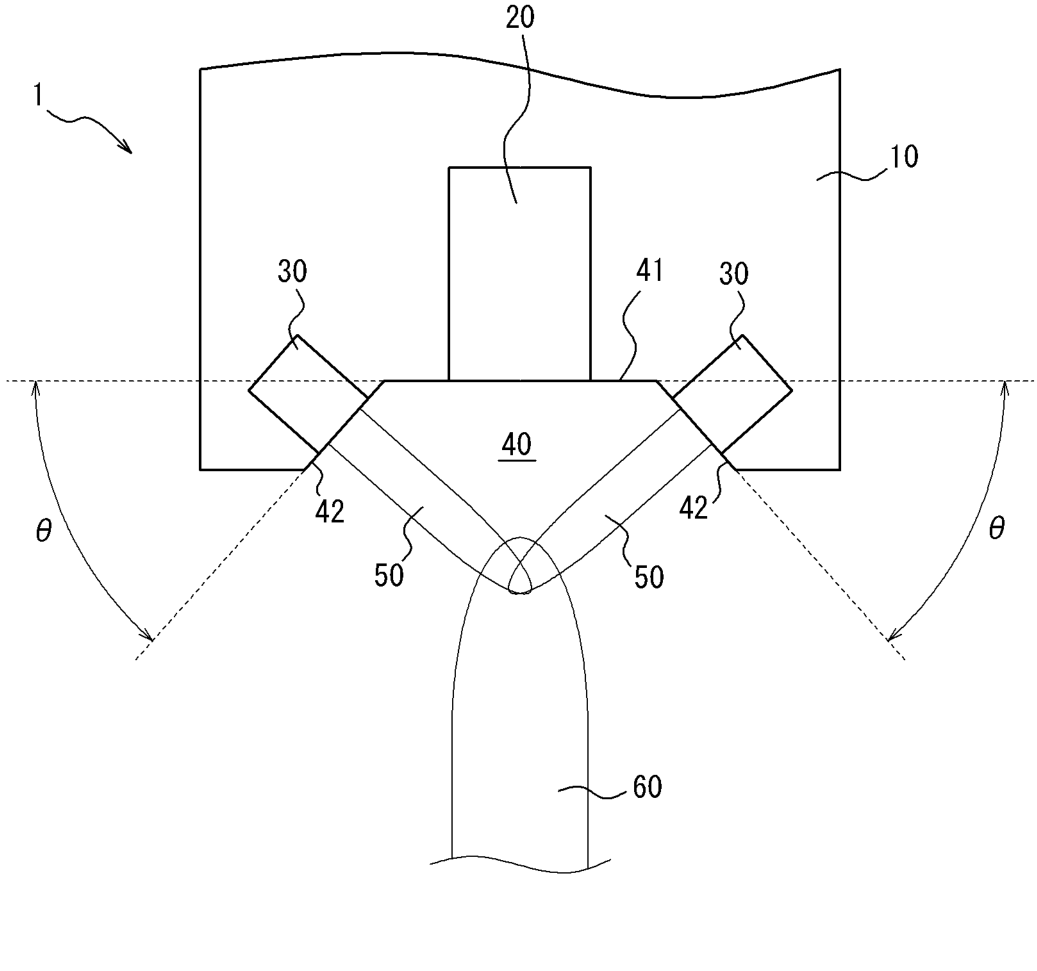


FIG. 2

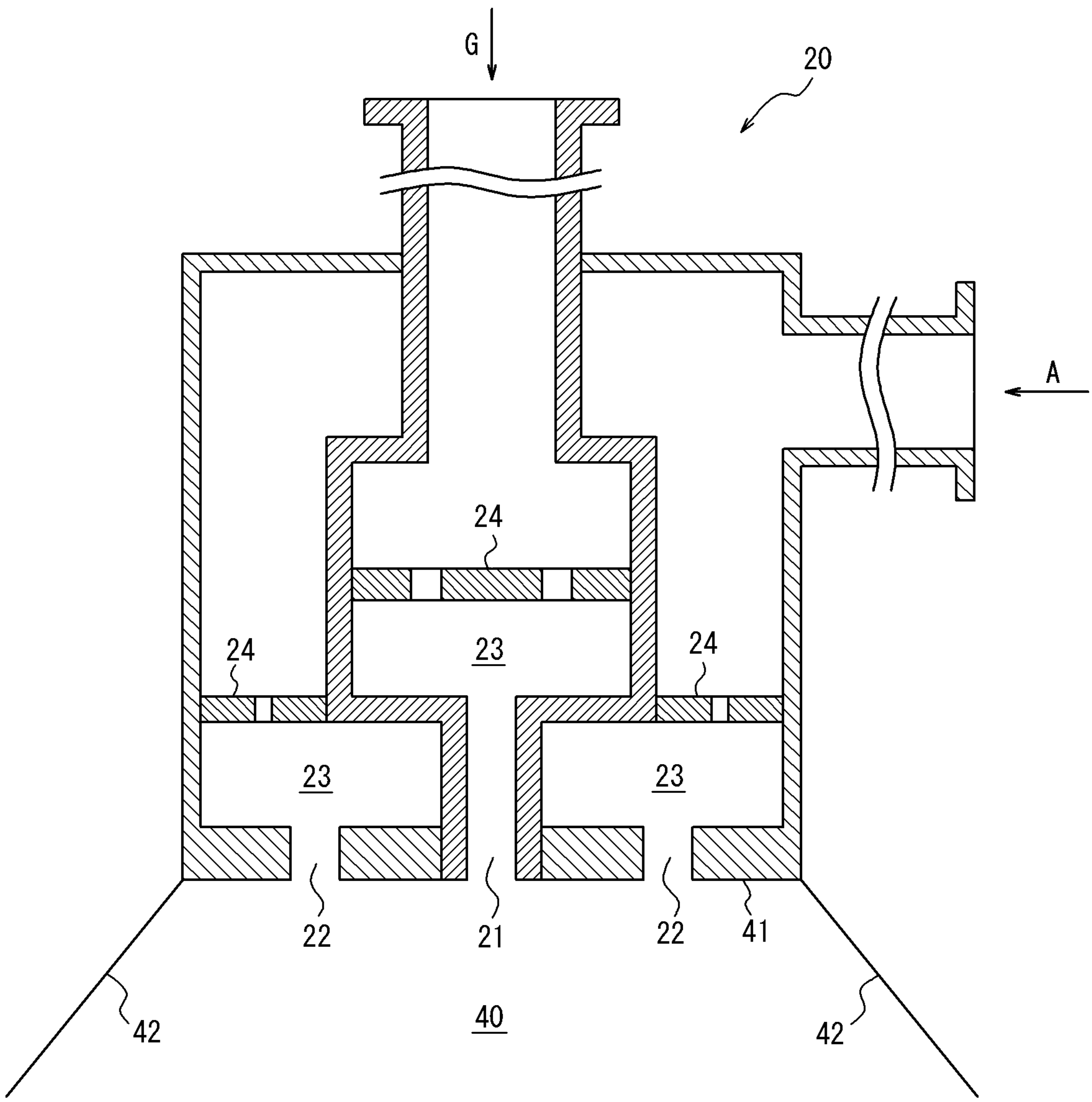


FIG. 3

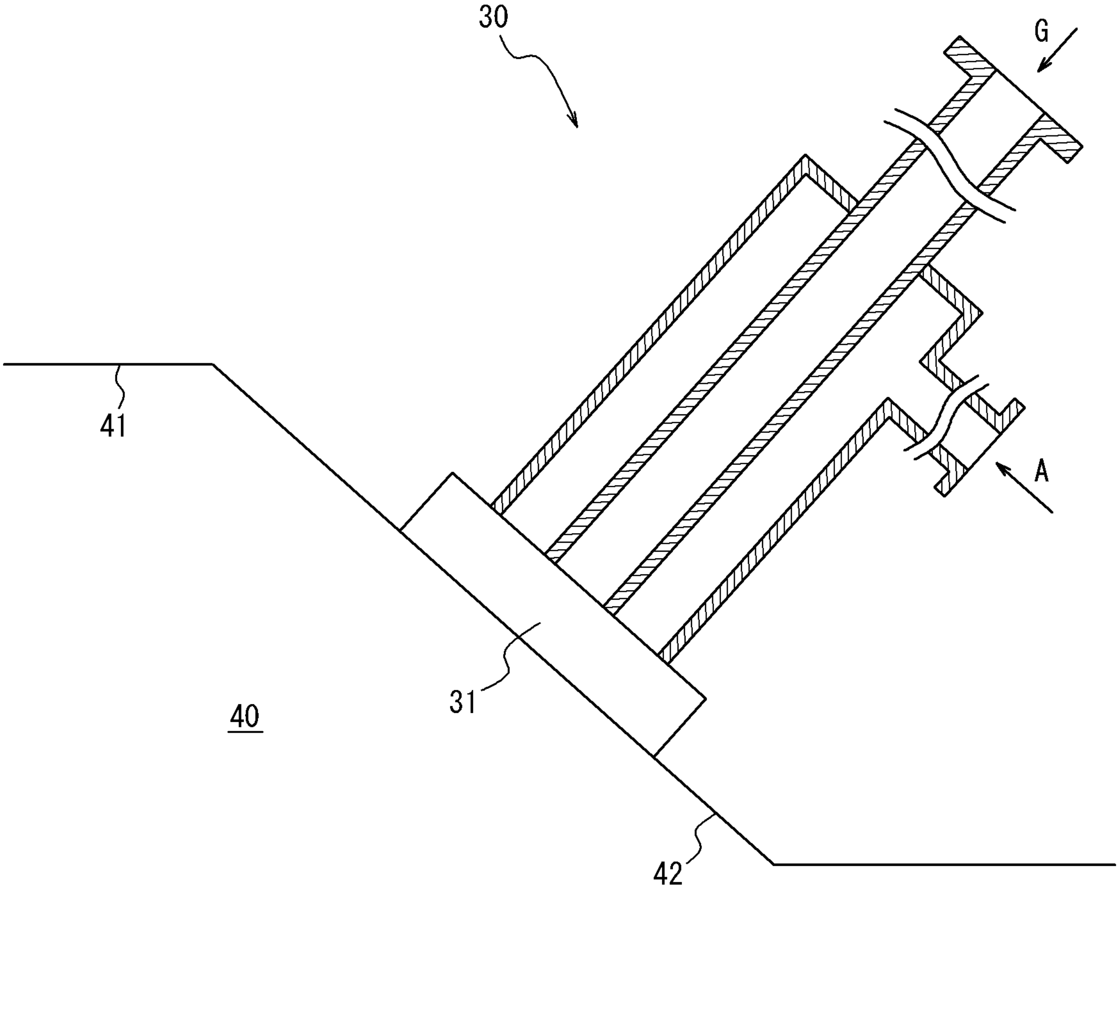


FIG. 4

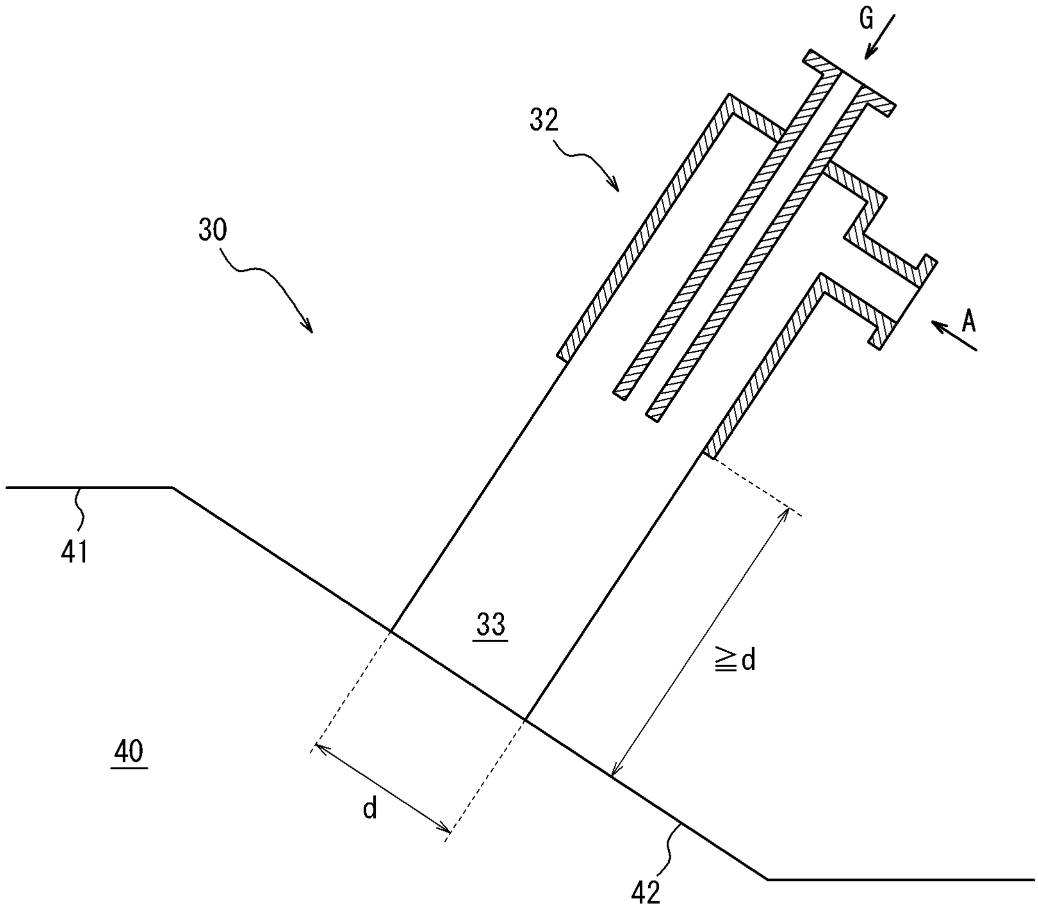


FIG. 5

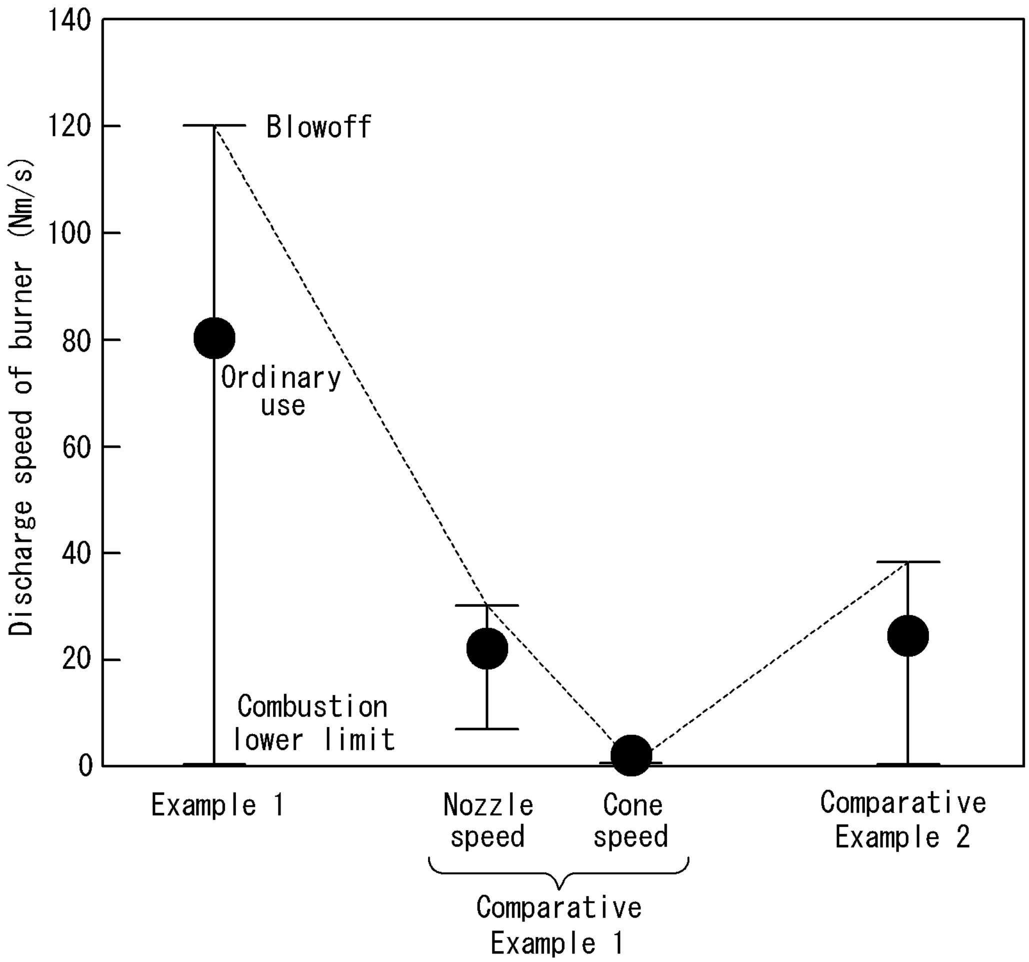

140
120
100
80
60
40
20
0
Discharge speed of burner (Nm/s)
Blowoff
Ordinary use
Combustion lower limit
Example 1
Nozzle speed
Cone speed
Comparative Example 1
Comparative Example 2

FIG. 6

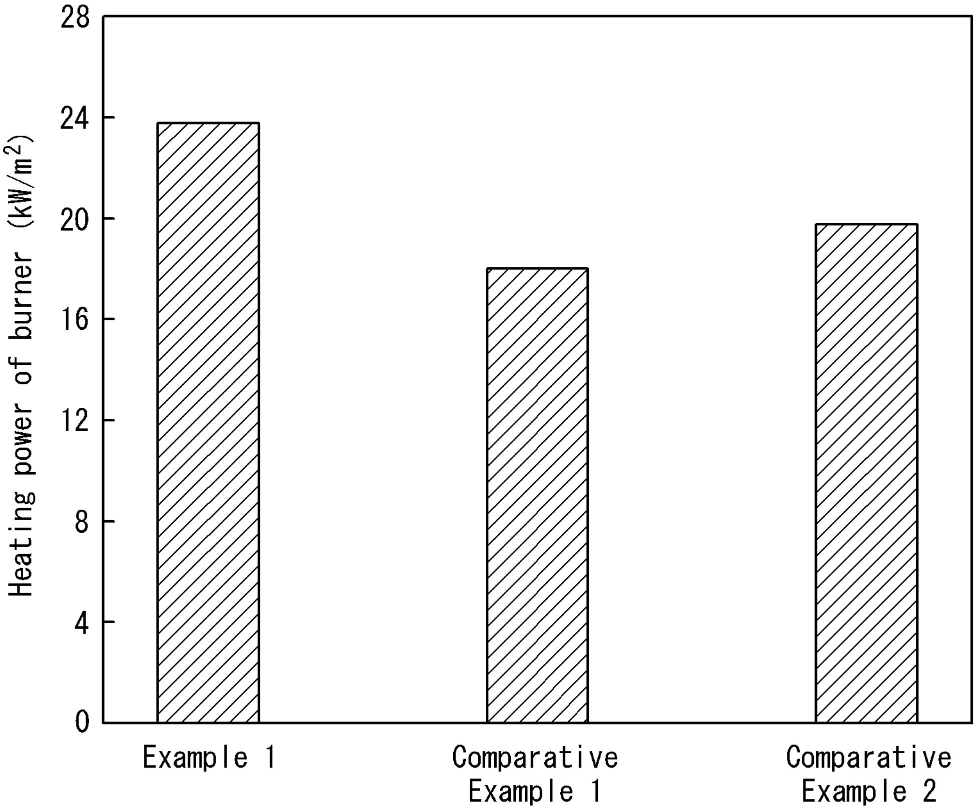

28
24
20
16
12
8
4
0
Heating power of burner (kW/m2)
Example 1
Comparative Example 1
Comparative Example 2

FIG. 7

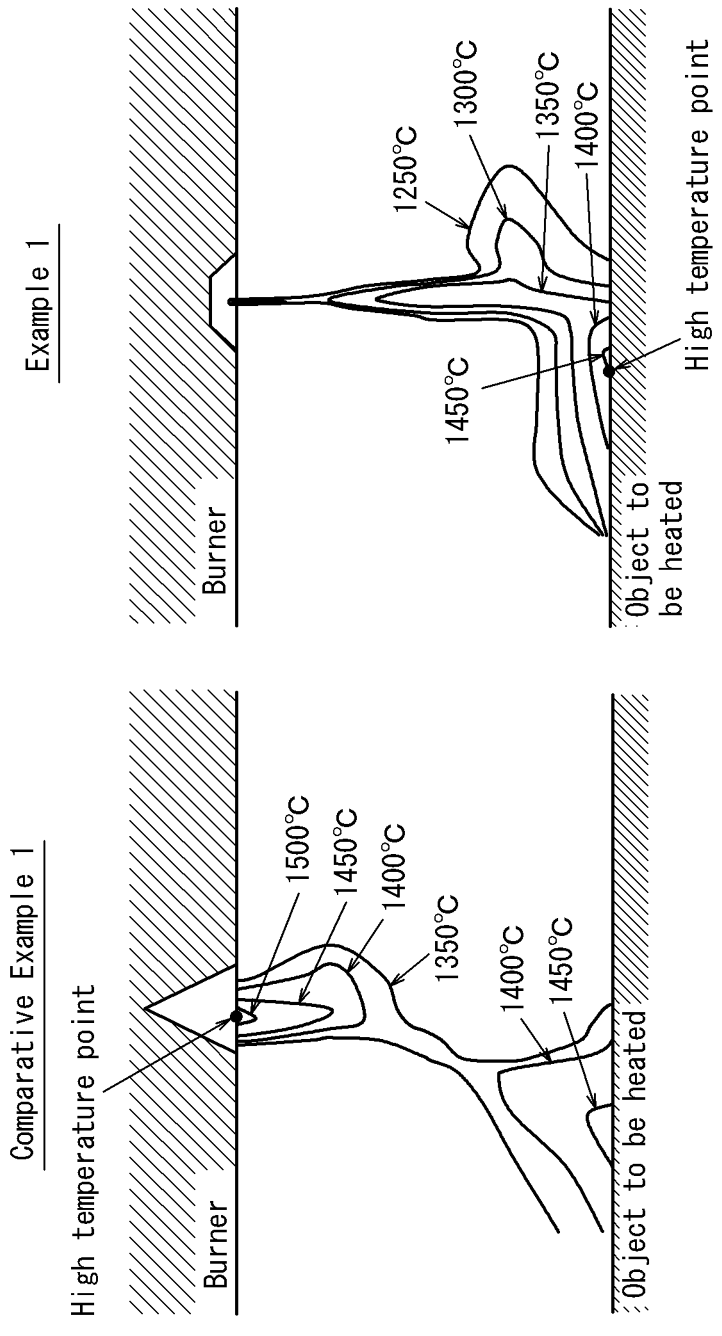
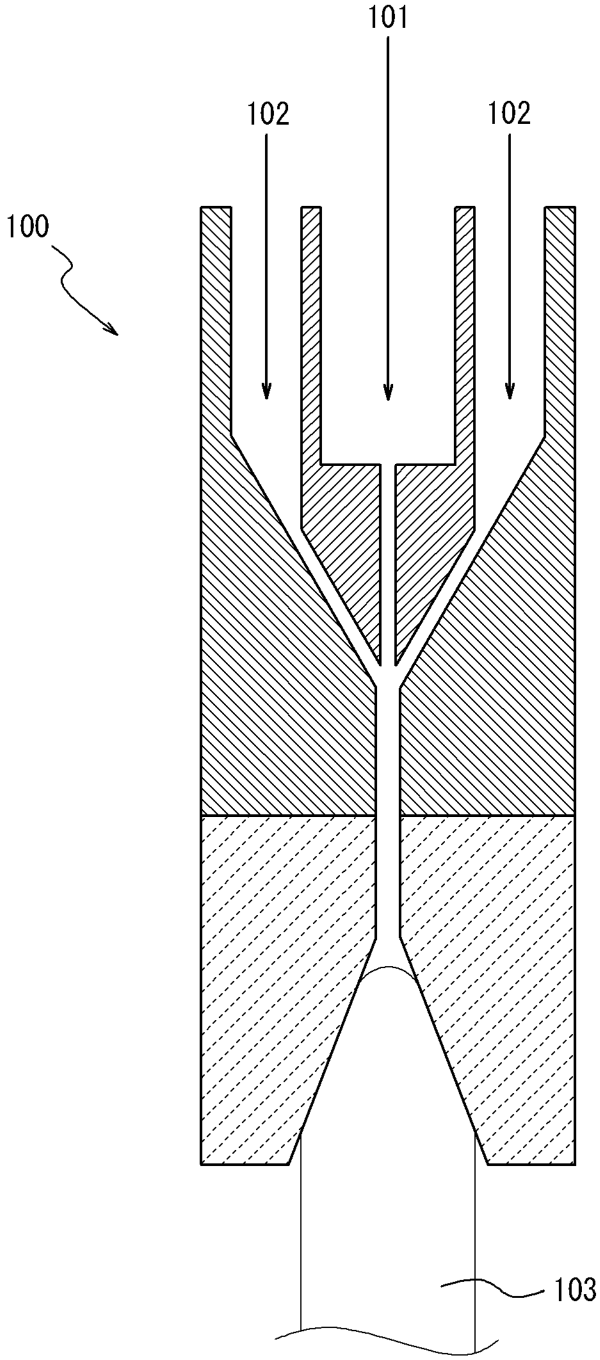

Comparative Example 1
High temperature point
Burner
1500°C
1450°C
1400°C
1350°C
1400°C
1450°C
Object to be heated
Example 1
Burner
1250°C
1300°C
1350°C
1400°C
1450°C
Object to be heated
High temperature point

FIG. 8



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2018/010774

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F23Q9/00(2006.01)i, F23D14/22(2006.01)i, F23D14/74(2006.01)i, F23Q9/02(2006.01)i

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)
Int.Cl. F23Q9/00, F23D14/22, F23D14/74, F23Q9/02

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	1971-2018
Registered utility model specifications of Japan	1996-2018
Published registered utility model applications of Japan	1994-2018

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.
X Y	JP 2014-201809 A (NIPPON STEEL & SUMIKIN ENGINEERING CO., LTD.) 27 October 2014, paragraphs [0025]-[0053], fig. 1-7 & CN 104100975 A	1 2-11
Y	JP 2013-194991 A (JFE STEEL CORPORATION) 30 September 2013, paragraphs [0018]-[0020], fig. 1, 2 (Family: none)	2-11
Y	JP 52-18234 A (EXXON RESEARCH AND ENGINEERING COMPANY) 10 February 1977, page 4, lower left column, line 3 to page 6, upper right column, line 3, fig. 1-4 & US 4175920 A; column 2, line 33 to column 4, line 42, fig. 1-4 & GB 1561711 A & DE 2611392 A1 & FR 2319846 A1	2-11

☒ 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
17 May 2018 (17.05.2018)	29 May 2018 (29.05.2018)

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

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2018/010774

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2017-36901 A (CHUGAI RO CO., LTD.) 16 February 2017, paragraphs [0017]-[0022], fig. 1 & KR 10-2017-0020255 A & TW 201712275 A	8-11
Y	JP 2016-191533 A (TAIYO NIPPON SANSO CORPORATION) 10 November 2016, paragraph [0046], claim 3 (Family: none)	10, 11
A	JP 6-159613 A (NIPPON FURNACE KOGYO KAISHA LTD.) 07 June 1994, entire text, all drawings (Family: none)	1-11
A	JP 2008-249280 A (TOHO GASU KABUSHIKI KAISHA) 16 October 2008, entire text, all drawings (Family: none)	1-11
A	JP 2015-4483 A (NIPPON FURNACE CO., LTD.) 08 January 2015, entire text, all drawings (Family: none)	1-11
A	JP 8-145315 A (TOYOTA MOTOR CORP.) 07 June 1996, entire text, all drawings & US 5846067 A & WO 1996/002793 A1 & EP 772001 A1	1-11
A	US 3302596 A (ZINN E. Robert) 07 February 1967, entire text, all drawings (Family: none)	1-11

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2013194991 A **[0006] [0007]**